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PAPERS AND PROCEEDINGS

OF

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Volume 102

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Royal Society of Tasmania

Papers and Proceedings Volume 102

Part 1.

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Royal Society of Tasmania

Annual Report for the Year 1967

The following report records in brief the activities of the Society during 1967.

The membership totalled 606 at the end of the year, including four Honorary Life Members.

The Council engaged in considerable discussion concerning the Society's Library which is very rich in Tasmaniana, as well as holding an excellent series of scientific publications.

Rising costs, lack of space and poor security relating to the Library greatly concern the Council which recognises the urgent need to improve the position. The Society, since its inception in 1843, has rendered great service to the development of the State, and has played an important role in preserving scientific records and archival material which is now of great value, particularly to the research worker. The question of space and security must find some real solution in the near future and the Council will continue its efforts to find a satisfactory solution. These are problems which should be of real concern to all members as the matter is one of real urgency.

During the year 425 volumes, books and journals, were added to the Library. Exchanges for the *Papers and Proceedings* of our Society accounted for the bulk of the journals.

The Annual Meeting was held in March and, as provided in the Rules of the Society, one Vice-President and two Council members were elected in place of those whose term of office had expired. Mr R. M. H. Garvie was elected Vice-President in place of Professor G. C. Wade, Mr E. C. Gifford was elected to Council in place of Mr E. R. Pretyman, and Dr E. R. Guiler was re-elected to Council having filled a casual vacancy for one year.

The positions of Honorary Auditor, Honorary Secretary and Honorary Treasurer were filled by Mr A. M. D. Hewer, Dr W. Bryden and Mr G. E. A. Hale respectively.

The following is a list of titles of talks given at the General Meetings held during the year:—

March: Mr V. C. Burley, State Chairman of the Advisory Council, C.S.I.R.O., on 'The Work of the C.S.I.R.O. in Australia with particular reference to Tasmania'.

April: Dr Campbell Duncan, Director of Pathology, Department of Health Services, on 'The Principles of Electron Microscopy'.

May: Illustrated lectures by members of the staff of the Tasmanian Museum and Art Gallery—

'Marsupials from our South-West' by Mr A. P. Andrews.

'Reflections on Asteroids' by Mr A. J. Dartnall.

'Tasmania—An Island of Volcanoes' by F. L. Sutherland.

June: The Honourable Mr Justice Crawford, on 'The Early History of the Law in Launceston'.

July: Mr T. H. O. Phillips, on 'Life in Post-Glacial Times'.

August: Mr J. H. Hemsley, Curator of Wildlife, Animals and Birds Protection Board, on 'Wildlife Conservation'.

September: Professor W. A. Townsley, Professor of Political Science, University of Tasmania, on 'The October Revolution of 1917. An Essay in Interpretation'.

October: Mr H. Lourandos, Archeologist and Anthropologist at the Tasmanian Museum and Art Gallery, on 'Archaeology and the Tasmanian Aborigine'.

November: Mr Max Angus, on 'What's behind Modern Art'.

Northern Branch

The Northern Branch in Launceston continued to hold meetings and to organise excursions. The arrangement with the main Library of the Society has continued whereby certain periodicals and books are sent to Launceston each month where these are available to members living in the north.

Papers and Proceedings

Volume 101 was published and the copies forwarded to the 320 libraries on our exchange list.

Acknowledgments

Without the generous help and assistance given by various libraries and many organisations and individuals the Society would not be able to function as it does. The Society is particularly grateful to and acknowledges the assistance provided during the year by, the Government of Tasmania; the Trustees of the Tasmanian Museum and Art Gallery; the Queen Victoria Museum, Launceston; the Press, Radio and Television stations; the State Library; and the many individuals who have assisted the Society so generously.

Northern Branch

Annual Report—1967

Following upon the elections held at the Annual General Meeting on 17 March, the Branch Council was composed as follows:—

Chairman—Mr Justice G. H. Crawford
Vice-Chairman—Dr J. C. H. Morris
Past Chairman—Mr T. E. Burns
Hon. Secretary/Treasurer—Mr W. F. Ellis
Council Members—Mrs M. P. Cameron, Mrs I. J. Mead, Mr J. N. Gee, Mr T. W. W. Sharpe, Mr K. E. J. Robinson.

Mr Justice Crawford and Mr Ellis were the delegates to the General Council of the Society and Mr Justice Crawford continued his term as the nominee of the Northern Branch on the Cradle Mountain-Lake St Clair National Park Board.

Membersip

The Branch membership at 31 December 1967 totalled 240.

Lectures

Eleven General Meetings and one Special Meeting were conducted at which the following lectures were given:—

24 *February*—'The Castra Scheme', by Mr G. T. Stilwell.

17 *March*—'Early Tasmanian Medicine' by Dr W. W. Wilson.

28 *April*—'The Changing Tasmanian Scene', by Mr J. B. Thwaites.

25 *May*—'Problems in Tasmanian Archaeology' by Mr Rhys Jones.

23 *June*—'Wildlife Conservation', by Mr J. H. Hemsley.

28 *July*—'The Thread of Geology', by Mr M. R. Banks.

24 *August*—'Die-back in Eucalypt Forests', by Mr R. E. Ellis.

22 *September*—'The Principles of Electron Microscopy', by Dr C. A. Duncan.

27 *October*—'The Work of the C.S.I.R.O.', by Mr V. G. Burley.

10 *November*—Special Meeting—'Bee Research in the World Today', by Dr Eva Crane.

24 *November*—'Aspects of the Mineral Industry', by Sir Henry Somerset.

7 *December*—Members' Night:—

'Aspects of the Geology of Central Australia' by Mr Justice Crawford.
'The Flora of Central Australia', by Mrs R. E. Ward.
'Croppies Point', by Mr D. Walter.
'Figures and Fantasies', by Mr J. N. Gee.
'Who was Captain H. S. Forth?', by Mr R. S. Smith.

Excursions

Four excursions were conducted, all of them being well attended:—

14 *May*—Fingal Valley.

30 *September*—Camden Forestry District.

21-22 *October*—St Helens-Seymour Area.

26 *November*—Isis River District.

Council

The Northern Branch Council met five times and was represented at three meetings of the Council in Hobart and at one sub-committee meeting.

Acknowledgments

The Branch Council records its appreciation of the Launceston City Council for the facilities at the Queen Victoria Museum which have been provided during the year.

THE PERSISTENCE OF DRIFT PUMICE, FROM THE 1962 SOUTH SANDWICH ISLANDS ERUPTION, IN SOUTHERN AUSTRALASIAN WATERS

By

F. L. Sutherland

(Tasmanian Museum, Hobart)

and

A. M. Olsen

(Department of Fisheries and Fauna Conservation, Adelaide, South Australia)

(With one text figure)

ABSTRACT

Drift pumice from the 1962 South Sandwich Islands eruption was observed to persist in Southern Australasian waters five and a half years after its eruption and over four years after its first appearance in these waters. Mostly fine pumice gravels and sands have been stranded since early 1965. Regular surface plankton hauls in Mercury Passage, east Tasmania, in the past two years indicated a number of influxes of the pumice into eastern Tasmanian waters. It is postulated that these influxes probably largely represent material recycled from earlier strandings, although some pumice may have arrived from continuous indirect drift. As yet there is no evidence to discount the possibility of circum-antarctic circulation of some of the pumice, before stranding.

Large amounts of pumice liberated by submarine volcanism in the vicinity of the South Sandwich Islands in March 1962 (Gass, Harris and Holdgate, 1963) were subsequently carried eastwards by the West Wind Drift System and distributed on southern Australasian coasts by 1964 (Sutherland, 1964, 1965; Simpson, 1965; Coombs and Landis, 1966). This note deals with further information on the initial distribution of the pumice along the Australian coast, and evidence of its persistence in southern Australasian waters.

Australian strandings of the pumice were first observed in Tasmania in late December 1963, a few months earlier than any reports previously received from the Australian mainland. However, A. D. Wadsley (pers. comm., 28 October 1965) states that he "found large pieces of pumice in and around the Torquay area during Xmas 1963-New Year's Day 1964 holiday period, coinciding with the time at which they were noticed on the west coast of Tasmania and considerably earlier than the report from Port Campbell, Victoria." Similarly, the previous earliest record of the pumice stranding on the Western Australian coast was in July 1964, but further data and samples forwarded by G. Kendrick and D. Merrilees, Western Australian Museum, indicate that some of the pumice washed up as early as March 1964. This Western Australian material may have been derived from the initial wave of pumice intruding into south-eastern Australian waters, while the heavy influx about mid 1964 was probably brought up from the south by strong southerly winds. In view of the discussion on the origin of past strandings of pitch on the south-eastern Australian coast (Sprigg, 1961) it is perhaps also worthwhile recording the presence of rare pieces of pitch amongst the pumice strandings on the north-west coasts of Tasmania in 1964.

Finer grained gravels and sands with sporadic larger pieces became the dominant pumice material washing up on Australian coasts by early 1965 (Sutherland, 1965) and further such strandings have been noted more recently. Thus, copious pumice gravel was observed washing ashore on 3 April 1965, half a mile north of Cape Martin, South Australia (D. Wolfe, pers. comm.). A fresh heavy deposit of fine pumice, up to an inch or two thick was noted on the southern Victorian coast in mid-October 1965 (A. D. Wadsley, pers. comm.), while fresh sparser pumice gravel was noted by one of the authors at Port Campbell in mid-January 1967. Similar strandings were present at a number of places on the western Victorian coast at about the latter time, although they were generally absent from the eastern Victorian coast (D. J. Taylor, pers. comm.) and this distribution appears compatible with the normal summer surface water circulation through Bass Strait (Vaux and Olsen, 1961). In Tasmania new strandings of fine pumice were noticed at Reidle Bay and Darlington on Maria Island, Spring Bay, Marion Bay, Eaglehawk Neck, South Arm, and other south-eastern Tasmanian beaches during the months of August, September and October 1966, and in mid-January 1967. There were similar strandings on the west coast of Tasmania at Point Hibbs in May 1965 (D. Duncan, pers. comm.) and south of the Pieman Heads in late January-early February (A. P. Bravo, pers. comm.) 1967 and at Trial Harbour in early November 1967 (A. J. Dartnall, pers. comm.). These presumably only represent some of the pumice influxes on the Tasmanian coast since the beginning of 1965, as widespread and systematic visiting of beaches was not attempted. Periodic influxes of pumice gravels and sands were reported from south-western and southern beaches in Western Australia through to South Australia in

July and early November 1966, and in about mid-January and mid-July 1967, while pieces much larger than usual were stranded on south-western beaches recently during August and September 1967 (D. Merrilees and G. Kendrick, pers. comm.). On examination, samples of pumice from a number of the above mentioned strandings and the South Sandwich Islands pumice were identical. Recent strandings of fine pumice were reported on the south coast of New Zealand (C. A. Landis, pers. comm.) and although samples have not yet been obtained for examination it is likely that they also represent the South Sandwich Islands pumice. Thus, a stranding at Mason Bay, Stewart Island on 7th January 1967 has been described as follows (Barlow, 1967); "There was a morning when the beach held an immense bridal-veil—miles of it. The receding tide had left behind an elaborate lace frill, flounce upon flounce, formed by millions of less-than-sago sized grains of pumice".

A detailed record of the occurrence of pumice in the surface waters of Mercury Passage, between the mainland of Tasmania and Maria Island, east Tasmania, was compiled by A. M. Olsen during surface plankton studies carried out over a period from September 1965 to July 1967. The sampling was either weekly or monthly over a day and night. The results (Table 1, fig. 1) indicate the presence of pumice at each plankton station with a positive sign and its absence with a negative, while double positives indicate the presence of particularly abundant pumice. Pumice was not detected in Mercury Passage on only five of the forty-four plankton sampling operations, namely 25/xi/65, 25/x/66, 16/xi/66, 5/xii/66, and 13/iv/67. In all the other sampling runs pumice was found at some, or all, of the plankton stations with particularly abundant pumice being found on 23/xii/65 and 30/xii/65. These results clearly demonstrate the continued presence of drift pumice in these waters some four years after reaching Macquarie Island and some three and a half years after its initial sighting on the sparsely populated west Tasmanian coast. The reports of new strandings on previously listed south-eastern Tasmanian beaches correspond with the presence of considerable quantities of pumice in plankton hauls in Mercury Passage. From these data it can be inferred that pumice influxes occurred (70% or more appearances in plankton tows) in early November 1965 and early December 1965 to early March 1966, becoming particularly abundant in late December 1965; late June 1966 to mid-September 1966; early October 1966; early February 1967; and mid to late June 1967. Similarly, obvious absences of drifting pumice can be inferred (i.e., pumice recovery from 30% or less of the plankton hauls on sampling runs) in late September, mid-October, and early to late November 1965; in late April, late September, early and late October, and mid-November to late December 1966; and in mid-March to early April 1967.

The southern coast of Tasmania is under the influence of the West Wind Drift System during both the summer and winter and therefore is not subject to the same influence of winter/summer surface water mass reversals as is northern and western Tasmania (Vaux and Olsen, 1961). Thus presumably much of the pumice appearing here represents material derived from lower latitudes working northwards, particularly so during the winter circulation. The summer influxes however, may contain some material that has worked further northwards and is being returned down to this south-eastern Australian area. Some of the pumice, possibly a considerable proportion, presumably represents re-cycled material from earlier strandings. This is probably true for many of the sporadic larger pieces found amongst the fine material as some of these show only immature growths of barnacles, and hence have not been continuously afloat. Particularly heavy pumice deposits were recorded following the initial arrival of the pumice at Heard Island (Budd, 1964) and Macquarie Island (Simpson, 1965) and probably much of this material has since progressively washed off and floated elsewhere.

The persistence of the South Sandwich Island drift pumice in Australian waters indicates that its dispersion continues some five and a half years after its eruption. This extensive volume of pumice was probably all from the initial eruption in 1962, although the possibility of further ejections from the volcano cannot be discounted. The complete pattern of the pumice dispersion is not clearly known, but much of the material swept eastwards from its source appears to be dispersing into higher latitudes. Calculations based on the arrival times of the initial pumice front at various places in the Southern Ocean gave an average speed of travel of about 18 miles per day (Sutherland, 1965). On these figures the pumice front carried by the West Wind Drift System would circumnavigate the Southern Ocean by about September 1964, and reappear in Australasian waters by about December 1965, providing that there was continued passage of material past the South American land mass. Observations on floating objects in the Southern Ocean (Deacon, 1960), would seem to support the possibility of circumnavigation by some of the pumice. Certainly, pumice was particularly abundant in the plankton hauls from Mercury Passage in late December (Table 1), but whether this was partly due to additional re-cycled material from the initial pumice front taking a longer indirect course or to the arrival of pumice recirculated around the Southern Ocean is debatable without further evidence. In any event, the persistence of the pumice in Australian waters provides additional confirmation as to the length of time such material can remain buoyant and the extent to which it can disperse over oceanic waters.

ACKNOWLEDGMENTS

The authors wish to acknowledge the assistance of numerous persons who kindly supplied information on, and samples of, the pumice drifts. In particular, they would like to thank Messrs. G. Kendrick and D. Merrilees of the Western Australian Museum, Dr C. A. Landis, Otago University, New Zealand, Dr A. D. Wadsley, C.S.I.R.O., Melbourne, Victoria, Mr D. J. Taylor of Melbourne, Mr A. J. Dartnall and Miss E. Aves, Tasmanian Museum, Hobart, Mr D. C. Wolfe, Fisheries Division, Tasmanian Department of Agriculture, Hobart, and Mr I. B. Jennings, Chief Geologist, Tasmanian Department of Mines, Hobart.

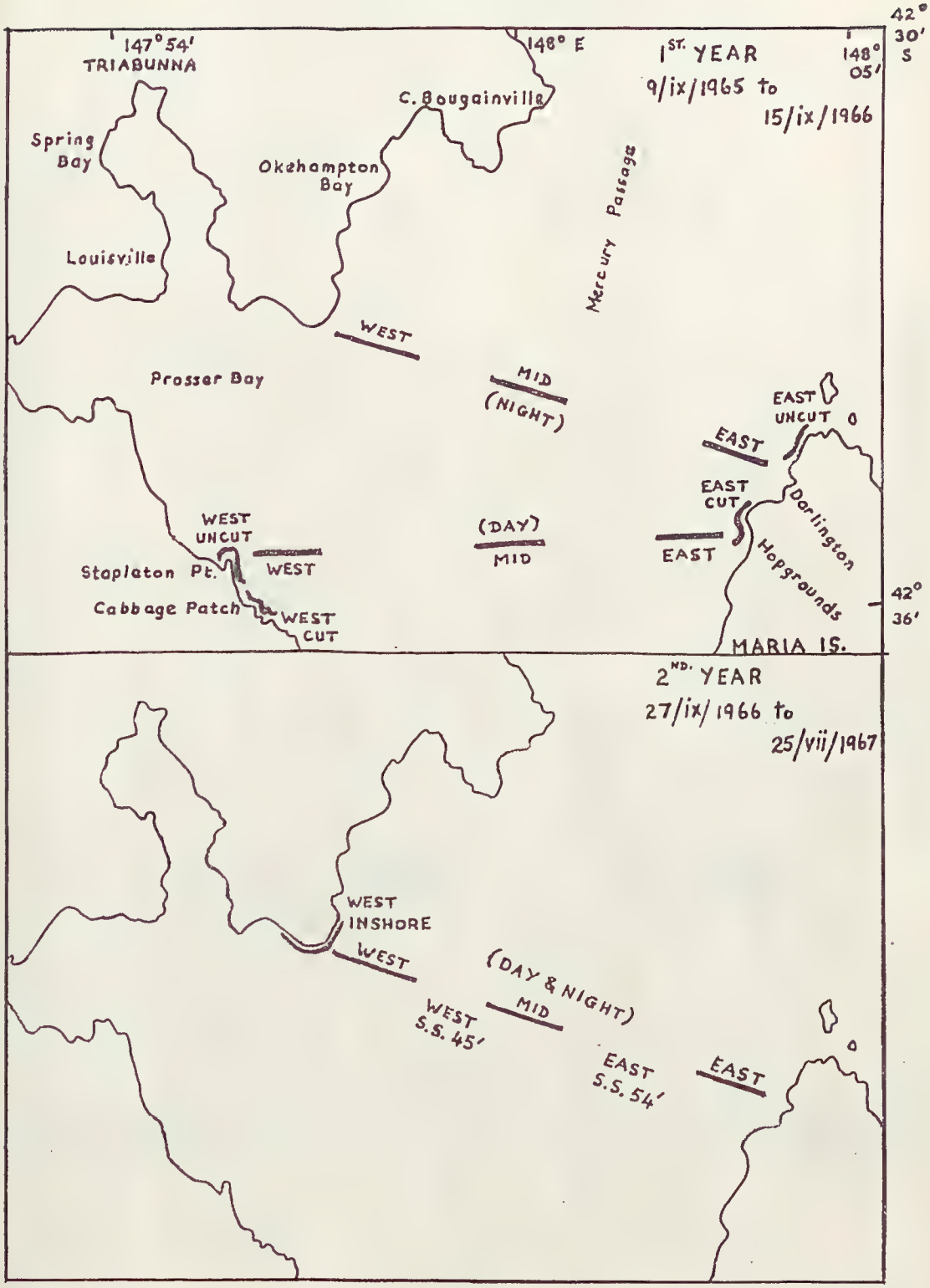
147° 54'
TRIABUNNA
148° E
148° 05'
42° 30' S
1ST. YEAR
9/ix/1965 to
15/ix/1966
C. Bougainville
Spring Bay
Okehampton Bay
Louisville
Mercury Passage
WEST
Prosser Bay
MID
(NIGHT)
EAST UNCUT
EAST
EAST CUT
Darlington
WEST UNCUT
(DAY)
MID
EAST
Hopgrounds
Stapleton Pt.
WEST
42° 36'
Cabbage Patch
WEST CUT
MARIA IS.
2ND. YEAR
27/ix/1966 to
25/vii/1967
WEST INSHORE
WEST
(DAY & NIGHT)
MID
WEST S.S. 45'
EAST S.S. 54'
EAST

FIG. 1.

TABLE 1. OCCURRENCE OF PUMICE AT PLANKTON STATIONS IN MERCURY PASSAGE, E. TASMANIA

Date	Day							Night		
	West Uncut	West Cut	Trans Passage West	Trans Passage Mid	Trans Passage East	East Uncut	East Cut	Trans Passage East	Trans Passage Mid	Trans Passage West
9. 9.65	+	−	−	+	+	−	NO	NO	NO	NO
WEEKLY—										
22. 9.65	−	−	−	−	−	−	+	−	−	+
5.10.65	−	−	−	+	+	+	−	−	+	−
13.10.65	−	−	−	−	+	+	−	−	−	−
19.10.65	−	−	−	+	+	+	+	+	+	−
27.10.65	−	+	+	+	+	+	+	−	−	−
3.11.65	+	+	−	+	+	+	+	+	+	+
10.11.65	+	+	−	−	−	−	−	−	−	−
18.11.65	−	−	−	−	+	+	+	−	−	−
25.11.65	−	−	−	−	−	−	−	−	−	−
3.12.65	+	+	+	+	+	+	+	−	−	−
9.12.65	+	+	+	+	+	+	+	+	+	+
15.12.65	+	+	−	+	+	+	+	+	+	+
23.12.65	++	++	++	++	++	++	++	−	−	−
31.12.65	+	+	+	+	+	+	++	+	+	+
MONTHLY—										
20. 1.66	−	−	+	+	−	+	+	+	+	+
9. 2.66	+	+	+	+	+	+	+	+	+	−
9. 3.66	+	+	+	+	+	+	+	+	+	+
21. 4.66	−	−	−	+	+	−	−	−	−	−
25. 5.66	−	+	−	+	+	+	+	+	+	−
21. 6.66	+	+	+	+	+	+	+	+	+	+
26. 7.66	−	−	−	−	+	+	+	+	−	+
18. 8.66	−	+	+	+	+	+	+	+	+	+
15. 9.66	+	+	+	+	+	+	+	+	+	+

First year Plankton Tows 9/9/1965 to 15/9/1966. NO — Not Occupied.

Kelp Beds	Location
West Uncut	.. Stapleton Point
West Cut	.. Cabbage Patch
East Cut	.. Hopgrounds, Maria Island
East Uncut	.. Darlington, North Maria Island

ADDENDUM

Drift pumice, similar in appearance to the South Sandwich Islands material, has washed ashore on the Juan Fernandez Archipelago, off South America, since August 1965 (Baker, 1967). This appears to indicate the passage of South Sandwich Islands pumice across the southern Pacific, driven by the West Wind Drift into the northerly flowing Humbolt Current.

Date	Day						Night				
	West Insh	*West*	*West SS*	*Mid*	*East SS*	*East*	*East*	*East SS*	*Mid*	*West*	*West Insh*
WEEKLY—											
27. 9.66 ..	−	−	−	−	−	−	−	+	−	−	−
7.10.66 ..	+	+	+	+	−	+	NO	NO	NO	NO	NO
12.10.66 ..	−	−	−	−	−	−	+	+	−	−	−
18.10.66 ..	+	+	−	+	−	+	+	−	−	−	−
25.10.66 ..	+	−	−	−	−	−	−	−	−	−	−
31.10.66 ..	+	−	−	−	−	−	−	−	−	−	−
10.11.66 ..	+	+	−	+	−	+	−	−	+	+	−
16.11.66 ..	−	−	−	−	−	−	−	−	−	−	−
21.11.66 ..	+	−	−	+	−	+	−	−	−	−	−
29.11.66 ..	−	−	−	−	−	+	−	−	−	−	−
5.12.66 ..	−	−	−	−	−	−	−	−	−	−	−
12.12.66 ..	−	−	−	+	−	−	+	−	−	−	−
19.12.66 ..	−	−	−	−	−	+	−	+	−	−	−
MONTHLY—											
10. 1.67 ..	−	−	−	+	−	+	+	−	−	+	−
8. 2.67 ..	+	+	−	+	−	+	+	+	+	+	+
15. 3.67 ..	+	−	−	−	+	+	−	−	+	−	−
13. 4.67 ..	−	−	−	−	−	−	−	−	−	−	−
7. 5.67 ..	−	−	−	−	−	+	+	−	−	−	−
21. 6.67 ..	+	+	+	+	+	+	+	+	+	−	−
25. 7.67 ..	+	−	−	+	+	+	+	−	−	−	−

Second Year Plankton Tows (modified programme) 27/9/1966 to 25/7/1967.
NO − Not Occupied.

Kelp Beds	*Location*	
West Inshore ..	.. Black Point Area	
West	.. West Mercury Passage	} Mercury Passage Tows
West SS ..	.. West Sub Surface (44 ft. depth)	
Mid	... Mid Passage	
East SS ..	.. East Sub Surface (55-57 ft. depth)	
East	.. East Surface	

REFERENCES

BAKER, P. E., 1967.—An Outline of the Geology of the Juan Fernandez Archipelago. *Geol. Mag.*, 104: 2, pp. 110-115.

BARLOW, MRS M., 1967.—Bird Watching and Beach-combing at Mason Bay. *The Southland Times*, Invercargill, Sat., 11th Feb. 1967.

BUDD, G. M., 1964.—The ANARE 1963 Expedition to Heard Island. *ANARE Reps. (A) Pubn. No.* 74.

COOMBS, D. S. and LANDIS, C. A., 1966.—Pumice from the South Sandwich Eruption of March 1962 reaches New Zealand. *Nature*, 209, 5020, pp. 289-290.

DEACON, G. E. R., 1960.—The Southern Cold Temperate Zone. *Proc. Roy. Soc.* B, 152, pp. 441-447.

GASS, I. G., HARRIS, P. G. and HOLDGATE, M. W., 1963.—Pumice Eruption in the Area of the South Sandwich Islands. *Geol. Mag.*, 100, pp. 321-330.

SIMPSON, K. G., 1965.—The Dispersal of Regurgitated Pumice Gizzard Stones by the Southern Skua at Macquarie Island. *The Emu* 65, 2, pp. 119-124.

SPRIGG, R. C., 1961.—Oil and Gas Prospects of the Gambier-Portland Basin. APEA 1961 Conference Papers.

SUTHERLAND, F. L., 1964.—Pumice from Tasmania. *Aust J. Sci.*, 26, p. 397.

———— 1965.—Dispersal of Pumice, supposedly from the 1962 South Sandwich Islands Eruption, on Southern Australian Shores. *Nature*, 207, 5004, pp. 1332-1335.

VAUX, D. and OLSEN, A. M., 1961.—The Use of Drift Bottles in Fisheries Research. *Aust. Fisheries Newsletter*, 20, 1, pp. 17-20.

A REVISED STRATIGRAPHY FOR THE PRECAMBRIAN IN NORTH-WEST TASMANIA

By

R. D. Gee

Geological Survey of Tasmania

(With one text figure)

ABSTRACT

Within the Proterozoic rocks of the Rocky Cape Geanticline in north-west Tasmania, three contrasting sedimentary assemblages are recognised. The Rocky Cape Group, which has been previously used very broadly, is redefined to include only one of these assemblages. The revised definition includes the orthoquartzite, siltstone and shale which form a continuous sequence in the Rocky Cape area. Some new formations are defined. The Smithton Dolomite, and related rocks, unconformably overlie the Rocky Cape Group to the west at Black River. The Burnie Formation is a thick sequence flanking the Rocky Cape Group to the east. The Rocky Cape Group and the Burnie Formation are separated by the Keith Metamorphics, which is a belt of low grade regional metamorphic greenschist, amphibolite and pelitic schist.

INTRODUCTION

The Rocky Cape Geanticline (Carey, 1953, p. 1115) consists of deformed, unfossiliferous, and dominantly unmetamorphosed sedimentary rock of presumed Proterozoic age.

Stratigraphical terminology in the Proterozoic succession in north-west Tasmania is mainly after Spry (1957a) who introduced several formation names. The sequence proposed was later modified (Spry, 1962, p. 111), as follows:—

Top—Cave Quartzite
Port Slate and Quartzite
Bluff Quartzite
Cowrie Siltstone
Base—Burnie Quartzite and Slate.

These formations were taken to constitute the Rocky Cape Group which was defined (Spry, 1957a, p. 81) as " those sediments chiefly quartzite slate dolomite and siltstone, outcropping intermittently from Penguin to Smithton and lying unconformably below the Dundas Group at Penguin. Its thickness is in excess of 10,000 feet ".

In addition, other formations have been named in north-west Tasmania, for example, Bryant Hill Quartzite (Carey and Scott, 1952), Smithton Dolomite (Spry, 1957b), Black River Dolomite (Spry, 1957a), and Forest Conglomerate and Quartzite (Spry, 1964, p. 47). Although these formations fall within the definition of the Rocky Cape Group, it is not clear, either from the original definitions or from current usage, whether they should be included in the Rocky Cape Group.

Recent work (Gee, 1967) has shown that the succession between Penguin and Smithton consists of three assemblages of contrasting lithological characteristics, each assemblage corresponding to a different basin of deposition. In accordance with the Australian Code of Stratigraphic Nomenclature (1964), it is unjustified to call this succession a group. Furthermore, there is a proved angular unconformity separating two of these assemblages.

Figure 1 summarises the stratigraphical relations of the rocks comprising the Rocky Cape Geanticline.

ROCKY CAPE GROUP

It is proposed that the Rocky Cape Group be restricted in definition to include only the formations of orthoquartzite siltstone and shale, some of which have been defined by Spry (1957a), which form a continuous sequence in the Rocky Cape and Dip Range area. This would include all those formations listed previously, with the exception of the Burnie Quartzite and Slate. It would also exclude the Smithton Dolomite, the Black River Dolomite and the Forest Conglomerate which unconformably overlie the sequence in question. This procedure retains much of the meaning of the original definition. The Rocky Cape Group is redefined below.

The Rocky Cape Group is that group of rocks, mostly quartzite, siltstone and mudstone, at least 16,000 *feet thick, consisting of the Cowrie Siltstone (at the bottom), Detention Sub-group, Irby Siltstone, Jacob Quartzite (at the top), and including any other formation which can be shown to be conformably above the Jacob Quartzite or conformably below the Cowrie Siltstone. It occurs in the general area around Rocky Cape, Sisters Hills, Dip Range, and Mawbanna.*

The Rocky Cape Group consists of one sub-group and three additional formations.

Cowrie Siltstone

Spry (1957a) proposed the name Cowrie Siltstone for the well-bedded siltstone which outcrops along the foreshore between Rocky Cape and Black River. At that time its stratigraphic position was not understood, but later Spry (1962, 1964) recognised that it lay beneath the orthoquartzite at Rocky Cape. In accordance with the usage of Spry, it is formally defined as follows.

The Cowrie Siltstone is that formation of finely laminated shale, well-bedded flaggy or laminated siltstone, and black mudstone, with some cross-bedded sandstone layers, lying conformably beneath the Detention Sub-group; it is approximately 8,000 *feet thick, and its type locality is on the western foreshore of Rocky Cape,* 1½ *miles from the point of Rocky Cape* (966,300y N, 332,500y E).

It occurs extensively on the flat plains between Sisters Hills and Black River, and also in the headwaters region of the Black and Dip Rivers but its outcrop is limited because of the cover of Tertiary basalt and Recent sediments. It outcrops along the foreshore in the vicinity of Cowrie Point.

The thickness of the Cowrie Siltstone is difficult to estimate because of a large transcurrent fault, and the effect of folding. The figure of 8,000 feet is an estimate based on an assumed regional dip with a correction for the transcurrent movement. The fold profiles at Cowrie Point indicate that the folding had little effect on the thickness.

Detention Sub-group

The Detention Sub-group is proposed to embrace the Bluff Quartzite, the Port Slate, and the Cave Quartzite of Spry (1957a). Mapping has shown that these three units taken together constitute the only mappable unit. The Port Slate of Spry is only 200 feet thick and cannot be traced for more than a few hundred yards. Thin, non-persistent lenses of siltstone comprise about 15% of the Detention Sub-group.

The Detention Sub-group is defined as that assemblage of dominantly cross-bedded orthoquartzite with minor interbedded non-persistent siltstone beds, lying conformably above the Cowrie Siltstone at Rocky Cape and below the Irby Siltstone at Sisters Beach. It is 4,600 *feet thick and has its type locality at Rocky Cape* (354,000y E, 967,000y N), *where it consists of the Bluff Quartzite, the Port Slate and the Cave Quartzite.*

The Detention Sub-group forms the dominant line of hills between Rocky Cape and Sisters Beach, and occurs on the Shakespeare Hills, the Sister Hills and the Dip Range.

Irby Siltstone

This is defined as that formation of black siltstone and minor dolomite and sandstone, lying conformably above the Jacob Quartzite. Its type locality is at Sisters Beach (358,500y E, 960,500y N). *It is named after Irby Flats behind Sisters Beach.*

The original thickness is not precisely known because it is an incompetent formation between two massive quartzite formations. At Sisters Beach it is about 2,500 feet thick.

Jacob Quartzite

This is defined as that formation of dominantly cross-bedded orthoquartzite with minor interbedded non-persistent siltstone horizons, being about 3,700 *feet thick, and having its type locality on the headland at Jacobs Boat Harbour* (364,500y E, 959,000y N), *after which it is named.*

It outcrops continuously along the coast between Sisters Beach and Jacobs Boat Harbour, and also forms the syncline on the hills just inland from Jacobs Boat Harbour. In the core of this syncline, forming the contorted southern block of the major east-west transcurrent fault, is about 200 feet of siltstone and mudstone overlying the Jacob Quartzite. This un-named siltstone is taken as the top of the Jacob Quartzite.

SMITHTON DOLOMITE

The Rocky Cape Group is overlain in the west by a blanket of dolomite which in places has a basal conglomerate layer. The widespread occurrence of dolomite in the Smithton district was first noted by Nye, Finucane and Blake (1934), and has been referred to frequently by many writers, including Carey and Scott (1952), and Hosking and Hueber (1954). Spry (1957b) formally defined the Smithton Dolomite as " the formation, chiefly dolomite, lying below the Dundas Group and above the Bryant Hill Quartzite of Carey and Scott (1952), being approximately 3,000 feet thick, with its type locality being immediately west of the Duck River, just north of the Smithton-Marrawah Road ".

Both Longman and Matthews (1962), and Spry (1962, p. 112, 1964, p. 47) noted the regionally transgressive nature of the Smithton Dolomite and have suggested an unconformity at the base.

The dolomite at Black River was named by Spry (1957a) the *Black River Dolomite*, who thought it was low down in the Rocky Cape Group. Later, Spry (1964) ascertained that the Cowrie Siltstone at Black River was overlain by conglomerate, quartz sandstone, chert, and then the Black River Dolomite. The Black River Dolomite is correlated with the Smithton Dolomite by lithological identity and close proximity to the Smithton Dolomite near South Forest and Irishtown (Gulline, 1959). Spry (1964) named the conglomerate and quartz sandstone that underlie the dolomite at Black River the *Forest Conglomerate and Quartzite* after the nearby village of Forest.

The sequence at Black River is as follows:—

Black River (Smithton) Dolomite	30 feet
blended chert	30 feet
quartz sandstone with cross-bedding	20 feet
conglomerate with minor sandstone	25 feet
unconformity	
Cowrie Siltstone	8,000 feet

In the Black River area there is an angular discordance between the Cowrie Siltstone and the Forest Conglomerate. The unconformity is best exposed in the bank of the Black River, exactly three-quarters of a mile west-south-west of the railway bridge across the river. Here the conglomerate dips 065°/60° NW and the siltstone dips 090°/61° N, giving an angular discordance of 22°. The base of the conglomerate transgresses across four feet of siltstone in a width of exposure of 15 feet.

The best indication of an unconformity is the presence of rectilinear grooves and ridges on the sole of the basal conglomerate bed. Superficially these ridges resemble incipient rotational or shear joint boudinage, however there are no joints in the conglomerate or siltstone having the required orientation. The ridges are the casts of sand and

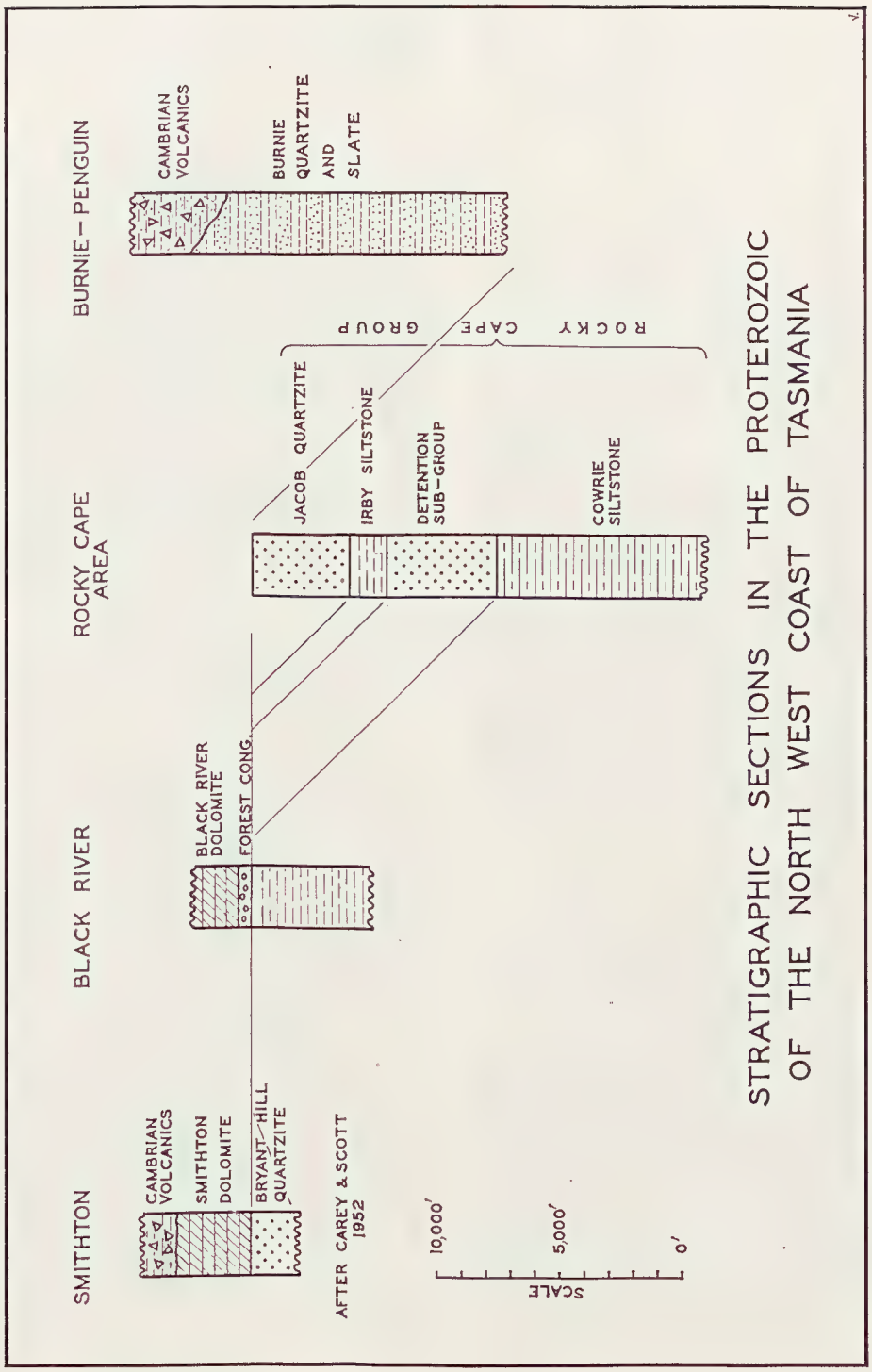
SMITHTON
BLACK RIVER
ROCKY CAPE AREA
BURNIE – PENGUIN
CAMBRIAN VOLCANICS
SMITHTON DOLOMITE
BRYANT HILL QUARTZITE
BLACK RIVER DOLOMITE
FOREST CONG.
JACOB QUARTZITE
IRBY SILTSTONE
DETENTION SUB-GROUP
COWRIE SILTSTONE
ROCKY CAPE GROUP
CAMBRIAN VOLCANICS
BURNIE QUARTZITE AND SLATE
AFTER CAREY & SCOTT 1952
SCALE
10,000'
5,000'
0'
STRATIGRAPHIC SECTIONS IN THE PROTEROZOIC OF THE NORTH WEST COAST OF TASMANIA
3019

Fig. 1.

fine-pebble infillings of depressions between small strike ridges on an erosional surface which truncates the bedding at an acute angle. The sharpness of these ridges indicates that the siltstone must have been compacted prior to the erosion. It is noteworthy that the cast ridges are present only when the size of the pebbles is less than the spacing of the strike ridges.

KEITH METAMORPHICS

The Rocky Cape Group is bounded on the east by a belt of low-grade greenshists. This belt can be followed from Wynyard south-west through Meunna to the Arthur River, and is a direct continuation of the Keith Beds of McNeil (1961). This ribbon-like belt is about four miles wide, and separates the Rocky Cape Group and the Burnie Formation. The schists are considered to be derived mainly from the surrounding sediments and partly from intrusive dolerite. The western contact, although gradational, is parallel to bedding in the adjacent Rocky Cape Group. These formations strike north-east with steep dips *facing the south-east* and in places are overturned. Thus the metamorphic rocks stratigraphically *overlie* the Rocky Cape Group. It is defined below as a rock-unit, considered to have been derived from sedimentary rocks which lie stratigraphically above the Jacob Quartzite.

The Keith Metamorphics is that assemblage of phyllite, muscovite schist, calcite schist, amphibolite and quartzite, originally named the Keith Beds; which forms a linear belt between Wynyard and the Arthur River near the Keith River, and probably extends much further to the south-west. It lies stratigraphically above the Rocky Cape Group, and its type locality may be taken as the area of best exposure which is where Hilder's timber road from Meunna meets the Arthur River (346, 000y E, 934,000y N).

BURNIE QUARTZITE AND SLATE

The Burnie Quartzite and Slate was defined (Spry 1957a, p. 81) as the "formation of subgreywacke quartzite and slate outcropping along the foreshore at West Burnie, and which appears to outcrop from Howth to Doctors Rocks, except where covered by later superficial material".

Spry (1962, 1964) suggested that the formation was the lowest in the Rocky Cape Group and the general dip was toward the west. Detailed mapping between Penguin and Doctors Rocks has shown that large tracts are overturned, and that formation is generally younging to the east. Therefore, the Burnie Formation appears to lie *above* the Rocky Cape Group, and to be separated from it by the Keith Metamorphics.

The Burnie Formation has a minimum thickness of 14,500 feet. It is a quartz wacke and slate assemblage containing minor pillow lavas, and is unlike the Rocky Cape Group. It was laid down in a different basin of deposition. Therefore it is not included in the Rocky Cape Group.

SUMMARY

In order to clarify the stratigraphic position of the Proterozoic rocks of the Rocky Cape Geanticline in north-west Tasmania, the Rocky Cape Group is redefined to include a conformable sequence of shale, quartzite and siltstone which has a discrete lithogenetic significance.

Unconformably overlying the Rocky Cape Group in the west is the Smithton Dolomite which has a basal conglomerate. The Burnie Formation to the east is younger than the Rocky Cape Group, but onlaps it rather than overlies it.

Separating the Rocky Cape Group and the Burnie Formation is a belt of metamorphic rocks called the Keith Metamorphics. This belt is interpreted as a high-angle shear zone of Proterozoic age.

ACKNOWLEDGMENTS

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REFERENCES

CAREY, S. W., 1953.—Geological structure of Tasmania in relation to mineralization. 5th *Empire Min. and Metal. Congr.*, 1, 1108-1128.

———— and SCOTT, B., 1952.—Revised interpretation of the geology of the Smithton district. *Pap. Roy. Soc. Tas.*, 88, 63-70.

GEE, R. D., 1967.—The tectonic evolution of the Rocky Cape Geanticline. Unpub. Ph.D. Thesis, University of Tasmania.

GULLINE, A. B., 1959.—The underground water resources of the Smithton district. *Underg. Wat. Supply Pap.* 5.

HOSKING, J. S. and HUEBER, H. V., 1954.—Limestones of Tasmania and their industrial development. *Tech. Pap.* C.S.I.R.O. (Build. Res.), 3.

LONGMAN, M. J. and MATTHEWS, W. L., 1962.—The geology of the Bluff Point and Trowutta Quadrangles. *Tech. Rep. Dep. Min. Tas.*, 6, 48-54.

MCNEIL, R. D., 1961.—Geological reconnaissance of the Arthur River Area. *Tech. Rep. Dep. Min. Tas.*, 5, 46-60.

NYE, P. B., FINUCANE, K. J. and BLAKE, F., 1934.—The Smithton District. *Bull. Geol. Surv. Tas.*, 41.

SPRY, A. H., 1957a.—Precambrian rocks of Tasmania, Part I. Dolerites of the North-west Coast. *Pap. Roy. Soc. Tas.*, 91, 81-93.

———— 1957b.—Precambrian dolomites of Tasmania, in Limestones of Tasmania. *Geol. Surv. Tas. Min. Res.*, 10, 32-38.

———— 1962.—The Precambrian rocks; in Geology of Tasmania. *Jour. Geol. Soc. Aust.*, 9, (2), 107-126.

———— 1964.—Precambrian rocks of Tasmania, Part VI. The Zeehan-Corinna area. *Pap. Roy. Soc. Tas.*, 98, 23-48.

WAVE TANK EXPERIMENTS ON THE EROSION OF ROCKY COASTS

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(With three text figures and one plate)

ABSTRACT

Erodable blocks representing vertical cliffs and shore platforms were exposed to attack by artificially generated waves. Maximum erosion in all blocks occurred above still water level. Vertical cliffs became deeply notched in a form which contained no horizontal portion and which had the lower segment located below still water level. Platform shapes were degraded by cutting on the platform surface and rounding of the leading edge. No wave-tank evidence was found to support the contention that high tide shore platforms are presently being formed by storm wave activity. Notches on the sides of the blocks were caused by acceleration of waves constricted between the block and tank sides. Such constriction and attendant increase in velocity may also favour rapid erosion in sea arches, caves and closely spaced stacks. Erosion debris moved rapidly from the base of the model cliff and was not involved in subsequent block notching.

INTRODUCTION

Hydraulic activity and various forms of mechanical and chemical weathering operate simultaneously in shaping rocky coastlines. Complexity of factors makes the isolation of any one aspect, such as hydraulic phenomena, very difficult in the field. Consequently, a model study was undertaken to gain an insight into the erosion forms resulting from hydraulic action alone. The method involved the direction of artificially produced waves of known characteristics against an erodable block representing a sea cliff. Experiments were conducted over a period of several months in a wave tank assembled for the purpose.

CONSTRUCTION OF WAVE TANK

Construction of the wave tank was simplified by the generous loan of a flume by the Engineering Department at the University of Tasmania. The flume, normally used for experiments in hydraulic flow, consisted of a tank with perspex sides of 9′ 6″ length, 8″ width and 16½″ height. It was only necessary to seal the flume at both ends in order to use it as a wave tank. The remaining construction work consisted principally of producing a paddle and driving arrangement to generate waves. The chief difficulty was that no alteration could be made to the existing flume and the paddle and drive units were fabricated to meet this requirement.

Out of the many different ways of making waves, it was decided to utilize a paddle pivoting on hinges fastened to a block at the bottom of the tank. The paddle was driven by a rod attached to a plywood disc by means of a nylon bushing turning on a stainless steel bolt. The bolt could be adjusted in a slot to vary the length of throw and hence the wave amplitude. The disc was driven by a stainless steel shaft on which was mounted a four-sheave V-belt pulley. Power for the V-belt was provided by a reduction box turned by an ⅛ h.p. electric motor. A variation in the period of the waves was attainable by moving the V-belt from one sheave to another.

The simulated offshore profiles offered minor difficulties. No holes could be drilled in the bottom of the wave tank for securing an adjustable profile ramp. Consequently it was necessary to use a gravel bed to form the required slopes. Gravel was placed in the tank and a steel plate laid on the surface to simulate an offshore profile. The plate was positioned by scooping gravel from one location to another until the desired profile was obtained. The gravel also served to hold the erodable blocks upright and in this capacity fixed the blocks securely enough to avoid movement upon wave impact. Wave reflection posed another problem. However, the reflections were reduced to an acceptable level by placing rubber-covered horsehair pads in both ends of the tank.

BLOCK CASTING

Production of the model cliffs themselves followed completion of the tank. A block was needed which was firm enough to stand unsupported in the water but incompetent enough to erode in this small-wave environment in a reasonable time. The first block contained a mixture of one part of mortar to 70 parts of sand. This mixture had been used successfully by the Tasmanian Hydro-Electric Commission hydraulics laboratory in model spillway erosion tests, but the block proved to be too weak to stand by itself in the tank when wet.

The second attempt utilized a stronger mortar mix; one part mortar to 35 parts sand. This block stood competently in the tank, even when wet, but was practically unerodable. It seemed evident that somewhere between a ratio of 1:70 and 1:35 would be found a mixture which would stand in the tank and also erode easily. However, the time necessary to mix and cure the mortar (on the order of four

days) indicated that another type of block would be more advantageous.

A suggestion was made to try plaster mixtures and a number of samples were prepared. A mixture of 50% plaster and 50% fine grained quartz sand resulted in a block which was much too hard. A mix of 25% plaster to 75% quartz sand was softer and more erodable, although the erosion rate was still fairly slow. The next block had a composition of 15% plaster to 85% quartz sand which had better erosion properties. A block composed of 10% plaster and 90% quartz sand was difficult to handle without breaking, but yielded rapid erosion. The final test mixture of 5% plaster to 95% quartz sand was extremely fragile and tended to crumble upon water contact.

A block containing 25% plaster and 75% sand was prepared and placed in the tank for the first run. This block and subsequent models were cast in the same mould and had dimensions of $16\frac{3}{4}$" x $5\frac{1}{4}$" x $2\frac{3}{4}$". The block was installed in the tank with its broad dimension ($5\frac{1}{4}$") facing the oncoming waves. Distance from block face to wave generating paddle was six feet, a dimension which was held constant for all the plaster block experiments.

BOTTOM PROFILE AND WAVE CHARACTERISTICS

With the block in place it was necessary to establish profile and wave characteristics. An offshore profile was needed which would produce properly breaking waves in the tank as well as simulate conditions found in the field. A deep profile, in which the depth of the shallow end was more than 1.25 of the wave amplitude, would create a reflective clapotis situation. A very shallow profile, on the other hand, would result in complete waves of translation. In this small tank proper water return for a complete wave of translation was not possible. In addition, many rocky coasts are fronted by depths of water sufficient to prevent waves from breaking completely. A profile depth was finally chosen which would yield a partial wave of translation superimposed upon a wave of oscillation. The steel plate which established the profile was placed $2\frac{1}{4}$" below still water level at the cliff face and $4\frac{1}{2}$" below the datum at a distance 24" from the block. The gravel bed under the plate sloped abruptly to the tank bottom at this point.

Wave characteristics were established to be compatible with the selected profile. Deep water wave height was $3\frac{3}{16}$" and wave length was $19\frac{1}{2}$". Thus the waves were oversteepened, with a value of 0.164, which would be similar to natural conditions in a storm. Wave period was 0.652 seconds. These parameters yielded a wave which started to break about 14" from the block face and which had broken through half of its height when it struck the vertical surface. Upon reaching the block, the total height of the broken wave between crest and trough had decreased to $2\frac{3}{8}$" from the unbroken amplitude of $3\frac{3}{16}$".

OPERATION

The tank was filled and wave paddle activated for run number P1 when the preparations were complete. The block was observed closely during this initial period for any signs of erosion. Within 20 minutes sand grains could be detected by feel on the previously smooth front face of the plaster-sand model. Water was shooting up the face to a height of six inches above still water level, but no visible notch was present. In the first hour of operation numerous pits, having an average diameter of about $\frac{1}{16}$", formed on the face. After four hours of continuous operation the pits had enlarged until a few had reached $\frac{3}{32}$" in diameter. A notch of $\frac{1}{32}$" average depth had formed on the face, in addition to other notches on the sides of the block. The side notches apparently resulted from the speeding up of the water movement as the breaking waves became constricted between the block and the tank sides. As the experiment progressed, the notches deepened through coalescence of the numerous pits. The paddle was stopped after a running time of 18 hours and 22 minutes at which point the block had spent a total of 31 hours and 47 minutes in the water. A profile was obtained by a tedious proces of cutting and recutting a cardboard template until template and block surface matched. In order to avoid possible errors through inclusion of the side notches in the frontal

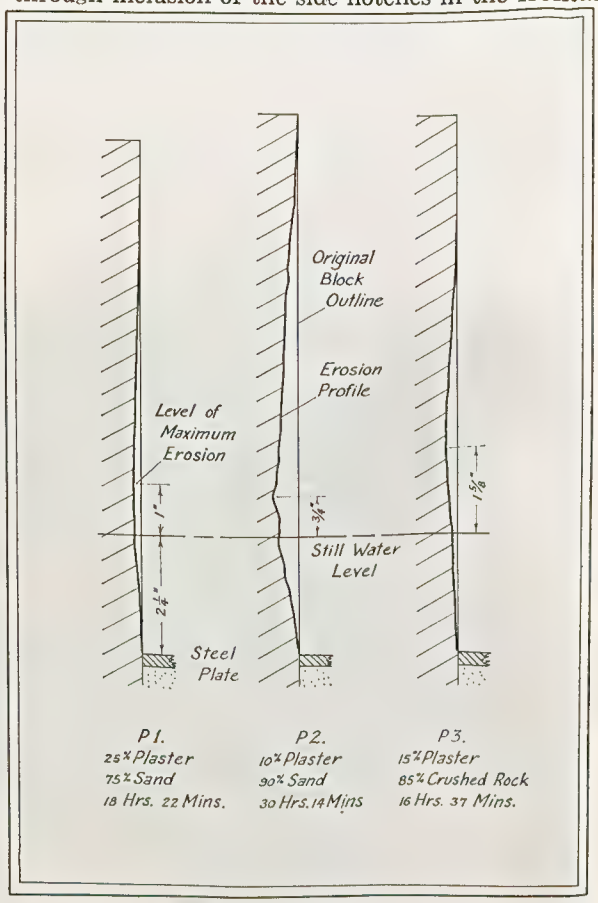

FIG. 1.—Erosion profiles of vertical cliff model Nos. P1, P2 and P3.

profile, the template was cut in the center of the block face. The profile resulting from this experiment is shown in Figure 1.

Another block was prepared with a mixture of 10% plaster to 90% quartz sand. This weaker mixture was intended to hasten the erosion process in order to get a better insight into the notching mechanism. Wave characteristics and the offshore profile were as identical as possible to Run P1. The rate of erosion proved to be greater on the new block, but the other characteristics remained the same. Sand grains were first evident on the face, followed by pitting, grooving and notching. Block P2 was eroded for 30 hours and 14 minutes before being removed from the tank. In contrast to run P1, Run P2 was continuous, with the immersion time equalling the running time. Block P2 showed a profile with greater depth and more irregularity than P1.

The third run, P3, was made with a plaster and crushed dolerite mixture. This was an attempt to simulate a natural condition in which jointing and bedding would be present. Crushed dolerite held in a matrix of plaster would furnish a coarser texture upon which the hydraulic action could work. The block was composed of 15% plaster and 85% crushed dolerite with an average diameter of $\frac{1}{8}$". This mixture was mechanically sound and yielded a block which suffered no crumbling in water and eroded satisfactorily. The offshore profile and wave conditions were identical to previous runs. The surface pitted rapidly on the new block and the material appeared more permeable. The notching continued as usual on the face, but exceptionally rapid erosion took place on the side of the block. Apparently the mixture was not uniform and the side of the block was less well cemented than the front. Throughout this run the side notch continued to cut across the face, with a greater cutting rate than on the front. The side notch cut higher as it neared the center of the block and also undercut the face notch to a depth of about $\frac{3}{4}$". The experiment was allowed to continue for 16 hours and 37 minutes over a period of two days and one night. The tank was drained during the time it was not in operation. In general the frontal profile attained is very similar to those of the plaster and sand blocks, except that the level of maximum erosion is higher (Figure 1).

Run P4 was an ill-fated experiment with a very rapidly eroding mixture. A block was produced which was 5% plaster and 95% quartz sand. The block started to crumble as the tank was being filled and was cracked even before installation. The top half of the block was held in place by hand and wave generation initiated. Erosion was rapid, especially laterally about $\frac{3}{4}$" behind the face. Before the block collapsed completely in about three to four minutes, a 1" notch had been produced on the struck face. Erosion was very rapid indeed but the block was mechanically too weak to stand in the tank.

Run P5 was conducted with a block which was 15% plaster and 85% quartz sand, cast in a platform shape. Unfortunately, before the block was placed in the tank the top half broke from the bottom section, leaving a joint where the two pieces fitted together. The block was set in the tank in spite of the fracture to allow experimentation to continue while a new block was being cast. The top section was clamped to a wooden support which braced the model sufficiently to withstand wave impact. As in the previous plaster blocks sand grains were detectable within a few minutes and pitting, grooving and notching followed. The notching, however, was of a different nature than in previous runs due to the platform configuration of the model. Cutting during Run P5 occurred in three separate areas: the leading edge of the platform, the platform surface and the cliff face. Considerable erosion also took place along the fracture at the base of the cliff.

After three hours of operation, the leading edge of the platform was rounded to a half-inch radius and notching was very apparent at the rear of the platform. Waves of translation were rolling across the platform and were deflected both upward and downward by the cliff. The waves that were deflected upward were removing material to a height of two to three inches above the platform surface and the portion of the wave which was deflected downward appeared to be scouring a notch in the platform surface itself, as well as into the base of the cliff.

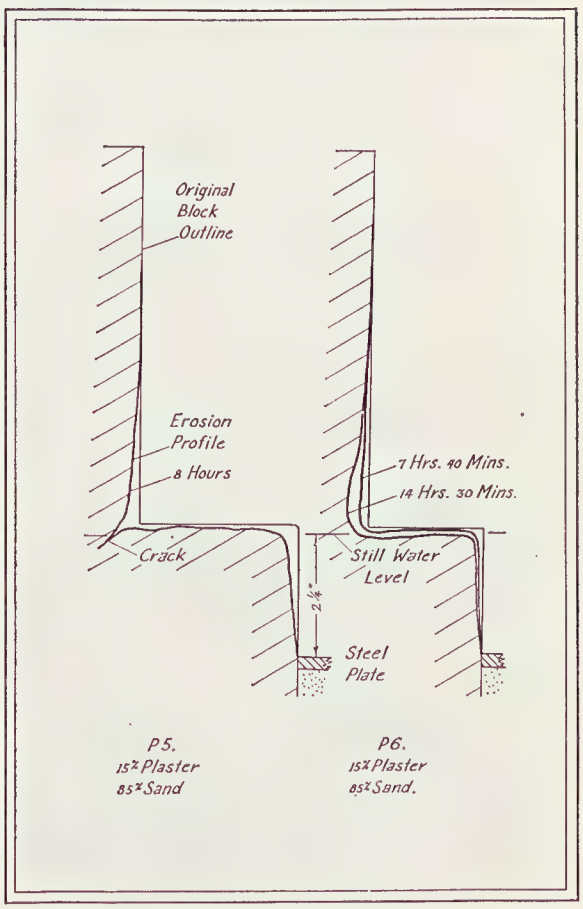

FIG. 2.—Erosion profiles of platform models Nos. P5 and P6.

The tank was drained after three hours and re-started on the following day. However, the tank was allowed to run for only five more hours before the final draining. The erosion patterns being created in this platform-shaped block warranted further study, but the top of the block was becoming insecure and it was necessary to stop. The profile attained during this eight-hour experiment is shown in Figure 2.

Another platform block was shaped in order to ascertain if the notching on the P5 platform surface was related to jointing in the broken block. The new block, P6, was also a 15%-85% plaster-sand mixture, but the platform profile was cut with a hacksaw instead of being cast in place as in the previous experiment. Cutting produced a markedly improved profile over that obtained by casting. Edges were completely square on the cut profile, while some rounding was inevitable with the casting technique.

The block was set in place, as previously, with the platform surface about $\frac{1}{8}$" above still water level. Shortly after starting the experiment the usual pitting and grooving occurred, becoming most pronounced at the rear of the platform. A notch cutting into the rear of the platform surface became evident after about two hours of operation. Erosion continued in this area throughout the 14 hour and 30 minute run, indicating that notching into the rear of the platform was not caused by the jointing in block P5. The final profile (Figure 2) shows deep cutting into the platform surface, leaving the leading edge area standing as almost a "rampart".

Blocks Nos. 5 and 6, in contrast to earlier models, had been placed in the tank with their narrow dimension facing the oncoming waves. The new position had the effect of reducing the reflected waves, and changing the standing wave condition in the tank to allow a purer incoming wave form. Some experimentation appeared necessary to determine the type of notching which would occur in a straight faced block (instead of a platform shape) inserted in this manner. Therefore, another plaster block was cast with a 15% plaster to 85% sand mixture.

The new block, No. P7, was installed in the tank and allowed to erode for a total time of 30 hours and 45 minutes over a three-day period, during which the tank was drained when not in operation. The results indicated that a similarity does exist in the notching forms of this block and the blocks with their broad dimension facing the waves. In both cases the maximum frontal notch development showed a good height correspondence with the portion of the wave which had broken (Figure 3). The greatest notching occurred between the level of the broken wave crest and the base of the turbulent zone. As the base of the turbulent zone was about halfway between the wave crest and the wave trough, maximum notching took place in the area struck by the upper half of the wave. Further examination of this phenomenon would have been useful, but the Engineering Department required the flume at this time for its own studies.

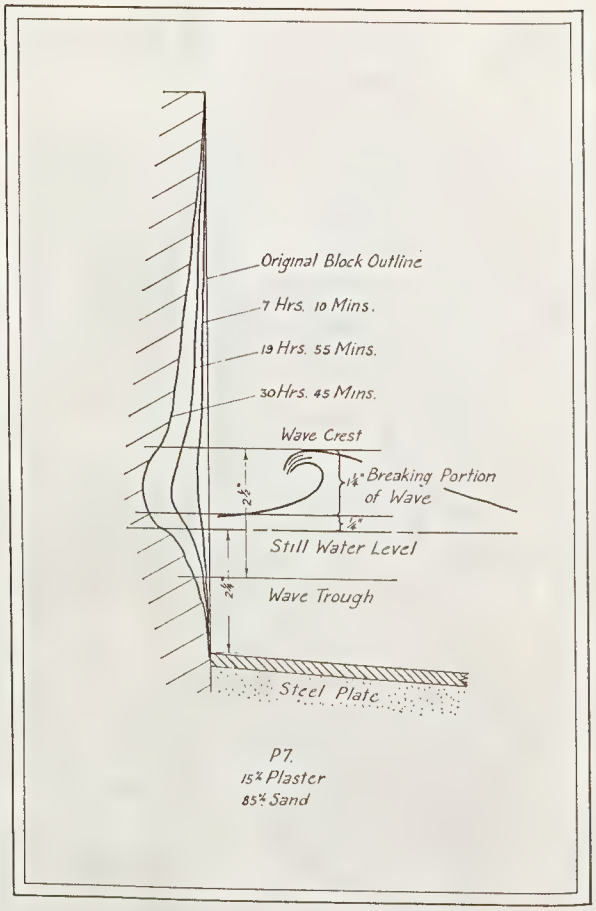

FIG. 3.—Erosion profile of vertical cliff model No. P7, showing relationship between erosion and breaking waves.

ANALYSIS OF RESULTS

The wave tank experiments indicated several characteristics of hydraulic action in a model coastal environment. The first aspect was the occurrence, in all blocks, of the maximum erosion at an elevation above still water level. A similar situation has been noted by engineers measuring the intensities of pressures created by waves breaking against upright surfaces in the shore zone. Two factors are involved in this phenomenon: (1) The entire wave form is shifted upward when decreasing depths are encountered (Plate 1, Figure 1) and (2) The upper part of the wave produces the highest pressures upon breaking. Bagnold (1939), in his wave tank experiments on the pressures produced by breaking waves on vertical walls, found maximum shock pressures between the wave crest and 0.6 H above the wave trough. The waves used were of 10-inch amplitude and had been displaced four inches upward in relation to still water level during progress up an incline before striking the wall.

Although conditions in the present experiment were not identical to Bagnold's, a general correlation between the zones of highest shock pressure and greatest erosion exists. On Block P7, a breaking wave 2⅜" high repeatedly struck the vertical face. In contrast to Bagnold's wave, this wave was displaced only 0.1 of its total height above still water level. The maximum erosion was centered in the upper half of the wave, ¾" below the crest (Plate 1, Figure 2). Inflection points between the concave curve of the zone of maximum erosion and the convex curve in adjacent areas occurred at the top of the breaking wave and at still water level. The zone of maximum erosion is thus extended further downward than Bagnold's maximum pressure area. Two reasons for the difference may be that wave and bottom characteristics are not identical and that Bagnold was measuring only shock pressures, while the plaster block cliff was reacting to wave shock combined with other activities associated with moving, turbulent water.

Other phenomena appeared when platform shapes were exposed to wave attack. A notch formed in the cliff face as expected, but cutting also occurred on the platform surface, especially at the rear. Cutting on the surface degraded the horizontality to a point where the horizontal plane of the platform had disappeared by the end of the experiment. The tendency for hydraulic action to establish smooth curves whenever possible became very apparent. Angular junctions of the surfaces at both front and rear of the platform were rounded into shapes approaching the elliptical "ogee curve" which offers least resistance to flow.

GENERAL CONCLUSIONS

Difficulty is always encountered when the attempt is made to relate a model study to the full-scale environment. The only thing that such a study really shows is that model waves of certain characteristics striking plaster-sand cliffs have a particular effect. For this reason no detailed analysis of the individual profiles was made, and only general conclusions were drawn. These general results, however, may be applicable in the real environment.

Workers in the field of shore platform study have stated that the greatest "storm wave" erosion would take place above mean sea level and these experiments suggest that this opinion may be correct. Bartrum (1924) typified this view when he ascribed platforms two feet above mean high water level to storm wave activity, acting on "homogeneous and resistant" rock. This concept has also been voiced by Jutson (1939) and other, more recent authors.

While the experiments support the contention that erosion is greatest at elevations above mean sea level, they fail to provide evidence that platforms may be produced by hydraulic action alone in a homogeneous, un-bedded and un-jointed material. Wave activity on the vertical model cliffs produced a rounded form with a deep notch and little horizontality. The lower half of the notch contained no horizontal component and was located below still water level. In addition, the pre-existing horizontality on the platform models was badly degraded by wave attack. If rounded notches with bases below mean sea level are produced in a similar manner by wave action in the real environment, some additional processes involving mechanical and chemical weathering will be required for the formation of level, elevated surfaces in many coastal rocks.

The notches created by accelerated flow along the sides of the blocks may also have full scale analogues. Formation of these notches, often as deep or deeper than the frontal depressions, may be related to the production of sea caves, arches and stacks. As the waves in the model study funnelled between the plaster-sand blocks and the tank walls, the water velocity was locally increased. The resulting pattern of erosion showed the greatest vertical dimension of the notch at the point nearest the wave source, but the maximum horizontal cutting at a point further towards the rear of the block where velocity was greatest. The relatively rapid erosion of arches and closely spaced stacks may be due to a similar increase in water velocity as wave energy becomes concentrated in narrow channels.

Another phenomenon which might have significance in the real environment was the behaviour of the material removed from the eroding blocks. The material was immediately swept away from the rock face and deposited in a break-point bar and a series of small ridges offshore. At no time was there a tendency for material to pile up at the base of the cliff as suggested by Cotton (1945). Cotton wrote that wave attack on a steep coast would not produce notching until sufficient talus had accumulated at the cliff base to act as cutting tools. The present experiments suggest that the talus would probably be transported offshore until a tremendous mass had accumulated and that erosion by unarmed hydraulic activity would have taken place in the interim.

Much more information could be derived from further wave tank experiments on erodable blocks. Throughout the present experiments, the wave characteristics and off-shore profile were kept as identical as possible from run to run. Interesting data might result from noting variations in erosion patterns as these parameters were changed. Experiments on multi-layered blocks containing differently resistant material would also be worthwhile, as would additional studies on jointed blocks. Finally, further refinement of method could add more quantitative information to the qualitative data already received, although scaling these occurrences in terms of material, time, size and distance would be difficult.

ACKNOWLEDGMENTS

I am indebted to Dr J. L. Davies of the University of Tasmania for helpful comments and advice. I would also like to thank Professor A. R. Oliver of the University of Tasmania, Engineering Department, for the use of his equipment and Mr W. F. Navin and the staff of the Hydro-Electric Commission Hydraulics Laboratory for their assistance

References

BAGNOLD, R. A., 1939.—Interim report on wave-pressure research. *Jour. Inst. of Civil Engineers*, London, June, pp. 202-226.

BARTRUM, J. A., 1924.—The shore platform of the west coast near Auckland: its storm wave origin. *Rep. Aus. Ass. Adv. Sci.* Vol. 16, pp. 493-495.

COTTON, C. A., 1945.—*Elements of Geomorphology*, Whitcombe and Tombs Ltd., London, 492 pp., p. 408.

JUTSON, J. T., 1939.—Shore platforms near Sydney, New South Wales. *Jour. Geomorphology, Vol.* 2, pp. 236-250.

ERRATUM—VOLUME 101

In the paper "Some formations close to the Permo-Triassic boundary in Tasmania" by M. R. Banks and I. H. Naqvi in the Papers and Proceedings of the Royal Society of Tasmania, Volume 101, pages 17-30, the term "Sphinx Rock Member" was inadvertently left uncorrected. This should have been "Mountain Lodge Member".

PLATE 1

FIG. 1.—Model wave just after breaking, oblique view. The wave form has been displaced upward with respect to still water level (represented by the top edges of the horizontal white lines on both sides of the tank). The block, No. P7, shows deep side and front notches and well developed pits. Eroded block material has accumulated offshore from the block on the steel profile plate.

FIG. 2.—Model wave striking block, oblique view. Broken portion of wave neatly fits into notch created by wave action. Greatest depth of notch is about ¾″ below wave crest at striking. Part of the wave has already passed the block and is being channelled between the block and the tank walls.

SOME RECENT MAMMAL RECORDS FROM THE LAKE PEDDER AREA, SOUTH-WEST TASMANIA

By

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(With two text figures)

ABSTRACT

Between 6 and 24 February 1967, an opportunity was provided for zoologists from the Tasmanian Museum, Hobart and the Queen Victoria Museum, Launceston, to conduct a biological survey in the Lake Pedder area, south-west Tasmania. The survey was conducted in three separate localities totalling about ten square miles in all. During October and November of the same year the Lake Pedder site was again visited by staff from the Tasmanian Museum in two field trips of one week each.

The areas are briefly described physically and the methods and results of the survey are outlined. The material collected is housed in either the Tasmanian Museum or the Launceston Museum, the relevant specimen numbers being given in the text.

When compared with more fertile areas of the State, the south-west area seems generally poor in both numbers and species of mammals although almost all indigenous Tasmanian groups are represented to some extent. The sparseness of the animal fauna would seem to be indicated by the low quality of the soils and vegetation and the few varieties of habitat.

A systematic list of the mammals collected is included, but owing to the short period of time available in the area, no information regarding the status and distribution is available.

INTRODUCTION

Lake Pedder, situated 24 miles south-west of Maydena, Tasmania, is a shallow fresh water lake at the south-eastern end of a flat, button grass plain drained by the Serpentine River. Although the lake has apparently been visited many times in the past and at present is a popular tourist attraction, no extensive biological survey work has apparently been done in the area. Records of any of the mammal groups from the area are noticeably absent from both the Tasmanian museums.

In February 1967, an opportunity was provided by the Hydro-Electric Commission of Tasmania, for zoologists from the Tasmanian Museum, Hobart and the Queen Victoria Museum, Launceston, to spend three weeks examining the area and making collections of the fauna for the museums. From what little is known of the mammals of the area it seemed that the publication of any new material would be desirable.

AREAS AND METHODS

Three separate areas were considered during the February survey—

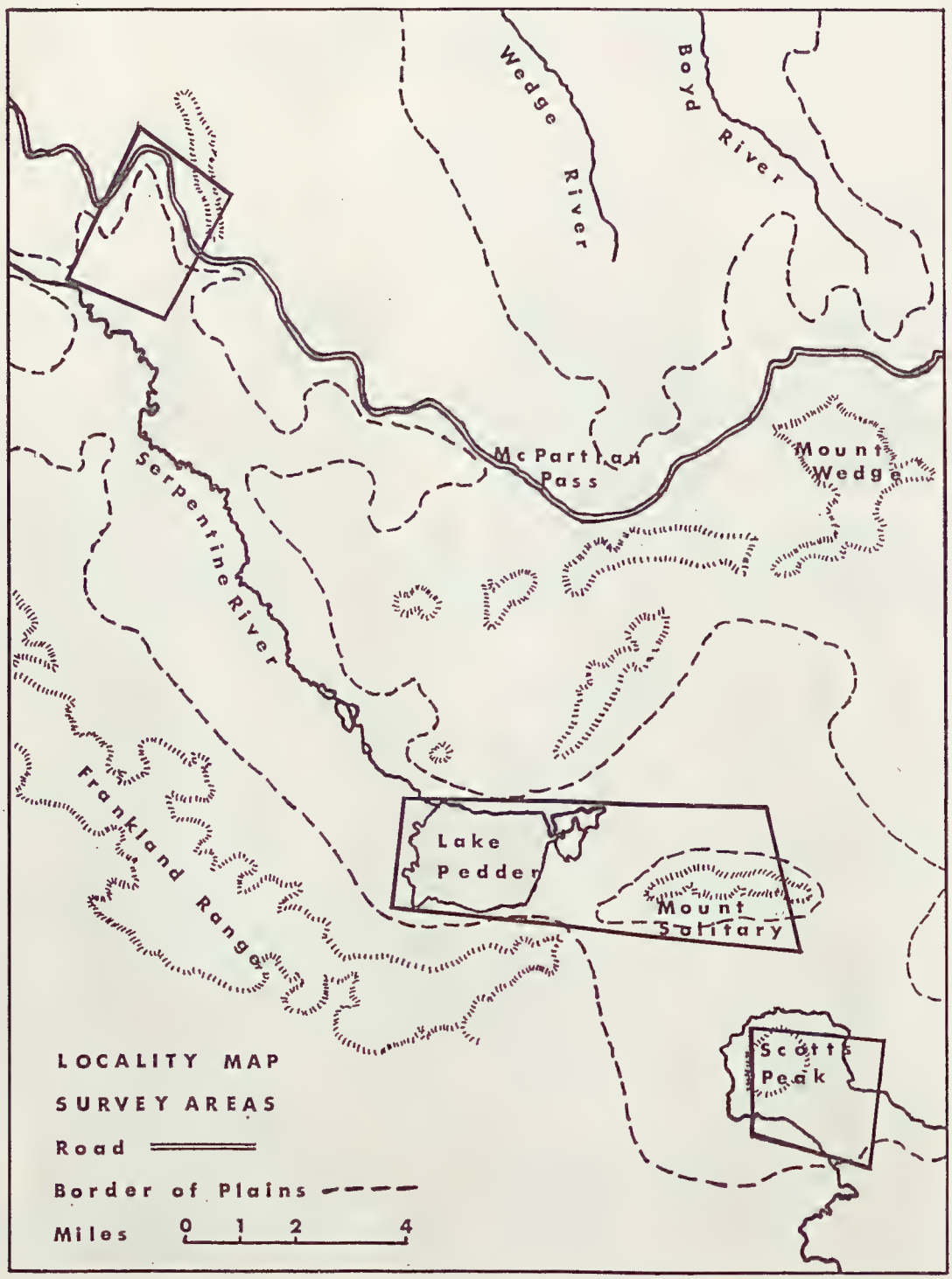
(1) Lake Pedder and the adjacent areas as far east as Mt Solitary.
(2) Scotts Peak and the areas around the upper Huon River.
(3) The north-western end of the Serpentine River plain through to the Gordon Road construction camp (see map).

Ten days were spent in the Lake Pedder area and all available methods of collecting were used. Both "snap-back" type and Sherman box traps were used in suitable areas where runways were found. Night spot-lighting and shooting was employed for Macropodidae, Phalangeridae and Dasyuridae. Daylight observations were made and representative areas were traversed on foot. Steel leg traps were set along some of the larger runways and in small clearings with baits suspended over them. Pit traps were dug on the beach but were unsuccessful owing to the tendency to become filled with water. Small "islands" of scrub in the button grass plains were examined and patches of typical rainforest investigated.

Five days were spent examining Scotts Peak and the surrounding areas. Large traverses were made across the country to the east and south, and night spot-lighting was used to establish visual records. Owing to the drier, more rocky nature of the plains, small ground level traps were only successful in the low scrub bordering the watercourses. In the upper Serpentine area the party was housed in the Gordon Road construction camp and road workers were questioned regarding the local fauna. In addition, the area was surveyed on foot; shooting and night spot-lighting from vehicles was employed, and traps were set in and around the camp. Much useful information was collected from road workers and several "road casualties" were brought in by them. During October and December of the same year, the Lake Pedder site was again surveyed by the author and the same methods employed as in February.

SYSTEMATIC ACCOUNT OF MAMMALS OBSERVED AND COLLECTED

The nomenclature used is taken from Iredale and Troughton's "Checklist of the Mammals Recorded from Australia" (1934) and the supplement to this by Ride (1964).


Wedge River
Boyd River
McPartlan Pass
Mount Wedge
Serpentine River
Frankland Range
Lake Pedder
Mount Solitary
Scotts Peak
LOCALITY MAP
SURVEY AREAS
Road
Border of Plains
Miles 0 1 2 4

The present locality of all specimens collected has been provided, those held by the Tasmanian Museum, Hobart, are prefixed by the letter "A", the specimens at the Queen Victoria Museum, Launceston, are prefixed by the letters "QVM". In the case of a species observed but not collected, all efforts were made to identify the species with reasonable accuracy by visual observations. Fortunately most of the species in this category were distinctive and unlikely to be mistaken for anything else.

ORDER MONOTREMATA

The Platypus (*Ornithorhynchus anatinus*) was observed in the canal draining Lake Maria into the north-east corner of Lake Pedder. This is a narrow waterway approximately a quarter of a mile long and about 25 yards across with steeply sloping sand banks on either side. At least two individuals were seen in February, both in the late afternoon and one (A775) male, was collected. Although the stomach contents were removed almost immediately after killing, digestion had proceeded too far for any of the contents to be identified. The species was again observed at the same site in December, but no specimens were collected.

Only one Echidna (*Tachyglossus setosus*) was observed during the entire survey, although reports from road construction workers would seem to indicate that the species may be more abundant than was recorded. The one specimen observed was found on a grassy slope to the south-west of Scotts Peak by the author in the late afternoon during February, but unfortunately the specimen could not be collected nor a photographic record obtained.

ORDER MARSUPIALIA

Family Dasyuridae

The Dasyuridae were the most numerous marsupials found on the survey and altogether four species were recorded. The Little Tasmanian Marsupial Mouse (*Antechinus minimus*) was found at all three localities and with the exception of those from the Gordon Road site all specimens were caught in traps, set on runways at ground level. The two from the Gordon Road camp were caught by spotlighting from vehicles along the road at night, and the species was also observed by the author in the scrub clearing alongside the road in the late afternoon.

It is interesting to note that an albino *Antechinus swainsoni* was also obtained from the Gordon Road area and appears to be the first record in Tasmania of albinism in this species.

The specimens are as follows:—

Antechinus swainsoni—A777 (male), Gordon Road.

Antechinus minimus—QVM 1967:1:14 (male), QVM 1967:1:12 (male), Scotts Peak; QVM 1967:1:13 (male), Serpentine; QVM 1967:1:11 (male), A801 (male), A802) (male), Lake Pedder; A767 (male), A769 (male), Gordon Road.

The name *Antechinus minimus* has been used here, but in a review of *Antechinus* Wakefield and Warneke (1963) have denoted the Tasmanian species by the name *Antechinus minimus minimus*.

The native cat (*Dasyurus viverrinus*) was found at Lake Pedder in February where at least two were occasional nocturnal visitors to the camp, and at the Gordon Road site. They were frequently observed on the beach at Lake Pedder by night spot-lighting during February and an adult female was collected by shooting in December. A conspicuous feature of the December trip was the large number of juvenile native cats observed in the late afternoon and evening.

Two males were collected from the Gordon Road site in February, Nos. A766 and A765 and one female from Lake Pedder in December (A812).

The Tasmanian Devil (*Sarcophilus harrisii*) on the evidence of tracks and droppings appeared to be present at all three sites but were only observed at Lake Pedder in February. Two males were collected, one by spot-light and the other by a bait suspended over leg traps—(A774) and (A776) respectively. In both cases the animals were caught at night and were examined for ecto-parasites.

Family Phalangeridae

Two representatives of this group were collected. The Tasmanian Ringtail Possum (*Pseudocheirus convolutor*) was found in the eucalypt timber bordering Lake Pedder and two specimens were taken by night spot-lighting. These were the only live specimens observed although the typical nests of the species were found in similar vegetation at all three sites. Specimens—QVM 1967:1:2 (female) and A773 (male).

The only other possum found was a single specimen of the Tasmanian Pygmy Possum (*Eudromicia Lepida*) which was caught by the author while night spot-lighting from a vehicle along the Gordon Road near the camp site (No. A772 male). Although the name *Eudromicia* has been used here, Wakefield (1963) has included both the Tasmanian Pygmy Possums in the single genus *Cercartetus*. No Phalangeridae were collected during the October-December trips.

Family Vombatidae

Although live wombats were only observed at the Lake Pedder site, evidence of tracks, droppings and burrows was abundant at all three localities. Many of the small " islands " of scrub and eucalypt timber between Lake Pedder and Mt. Solitary were found to contain active wombat burrows and holes were found in many of the patches of scrub on the slopes of Mt. Solitary and Scotts Peak. The animals were observed by spot-light on the beach at Lake Pedder and at night could be heard in the scrub near the camp site. No specimens were collected as the species could be readily identified and facilities for preserving larger animals were limited. The species was observed at Lake Pedder on all three survey trips.

Family Macropodidae

The only member of the kangaroo family recorded was the Scrub Wallaby or Bennetts Wallaby. As the species could be identified with reasonable accuracy by visual observation no specimens were taken although a road casualty at the Gordon Road site was examined by the author. At least three were observed at Lake Pedder, and a pair at Scotts Peak appeared to be almost tame, and accepted apples left for them by the party. Frequent evidence was found in the areas of scrub surrounding Lake Pedder and characteristic footprints of the group were found on the soft mud left by the evaporation of small pools.

ORDER RODENTIA

Despite quite intensive trapping and examination of likely areas, only three species of the rodent group were found in the area. The low scrub and button grass bordering rivers and small watercourses was almost invariably found to have an underlying network of small runways, but although upwards of 20 traps were set in areas on some occasions, yields were comparatively low. Some time was also spent examining and trapping in rainforest areas but with negative results.

Family Muridae

The eastern swamp rat (*Rattus lutreolus*) was obtained along the eastern border of Lake Pedder using both " snap-back " and box traps. The species appeared to share the same runways with *Antechinus* and *Mastacomys* and in one locality all three species were trapped within an area of about 20 yards diameter. Altogether four specimens of *Rattus lutreolus* were collected in February—QVM 1967:1:4 (female), QVM 1967:1:15 (male), A771 and A768. Nos. A799 (female) and A811 (male) were collected in October-December.

During the October trip a single specimen of the Long-tailed rat (*Pseudomys higginsi*) was collected from the Lake Pedder site, No. A800 (male). *Rattus lutreolus* was obtained on the same trap site in both October and December, but no further specimens of *Pseudomys* were obtained.

The Broad-toothed Rat (*Mastacomys fuscus*) was trapped at Lake Pedder and the Serpentine. Three specimens in all were collected, all were from fairly widely separated areas and in each case *Rattus lutreolus* was found on the same trap site. The locations were as follows:—QVM 1967:1:16 (female), Serpentine; QVM 1967:1:13 (female), Lake Pedder; and A770, Lake Pedder.

TABLE 1

List of Mammals Collected and Observed in the Area.

ORDER MONOTREMATA

Family:—**Ornithorhynchidae**

(1) *Ornithorhynchus anatinus* (Shaw and Nodder, 1799)
(Platypus)

Family:—**Tachyglossidae**

(2) *Tachyglossus setosus* (Geoffroy, 1803)
(Echidna)

ORDER MARSUPIALIA

Family:—**Dasyuridae**

(3) *Antechinus swainsoni* (Waterhouse, 1840)
(Dusky Marsupial Mouse)

(4) *Antechinus minimus* (Geoffroy, 1803)
(Little Tasmanian Marsupial Mouse)

(5) *Dasyurus viverrinus* (Shaw, 1800)
(Eastern Native Cat)

(6) *Sarcophilus harrisii* (Boitard, 1841)
(Tasmanian Devil)

Family:—**Phalangeridae**

(7) *Eudromicia lepida* (Thomas, 1888)
(Tasmanian Pygmy Possum)

(8) *Pseudocheirus convolutor* (Oken, 1816)
(Tasmanian Ringtail Possum)

Family:—**Vombatidae**

(9) *Vombatus* spp.
(Wombat)

Family:—**Macropodidae**

(10) *Wallabia* spp.
(Scrub Wallaby)

ORDER RODENTIA

(11) *Rattus lutreolus* (Gray, 1841)
(Velvet Furred Rat)

(12) *Pseudomys higginsi* (Trouessant, 1899)
(Long Tailed Rat)

(13) *Mastacomys fuscus* (Thomas, 1882)
(Broad Toothed Rat)

ACKNOWLEDGMENTS

The author is indebted to the Hydro-Electric Commission of Tasmania and to the Trustees of the Tasmanian Museum for providing the time and facilities needed to carry out the survey. Thanks are also due to the other members of the party, in particular Mr A. J. Dartnall, Mr J. B. Thwaites and Mr J. L. Swift all of whom rendered invaluable assistance in the field. I would also like to thank the members of the Gordon Road construction gang and other Commission employees who provided information and specimens.

Dr W. Bryden kindly read and criticised the manuscript and the specimens held by the Tasmanian Museum were prepared under the supervision of the Senior Preparator, Mr D. P. Alexander.

References

Davies, J. L., Nicholls, K. D. and Dimmock, G. M.—*Atlas of Tasmania*. Ed. Davies, J. L., Lands and Surveys Dept., Hobart, 1965.

Iredale, T. and Troughton, E. le G.—"A check list of the mammals recorded from Australia". *Australian Museum Memoir* VI, May 1934.

Ride, W. D. L.—"A list of mammals described from Australia between the years 1933 and 1963". *Supplement to Australian Mammal Society.* Bulletin No. 7, January 1964.

Wakefield, N. A. and Warneke, R. M.—"Some Revision in Antechinus (Marsupialia)". *The Victorian Naturalist,* Vol 80 (7), 1963.

Wakefield, N.A.—"The Australian Pygmy Possums". *The Victorian Naturalist,* Vol. 80 (4), August 1963.

ASTERODISCUS TRUNCATUS (COLEMAN, 1911)—A NEW RECORD FOR TASMANIAN WATERS

By

A. J. Dartnall

ABSTRACT

Three specimens of the sea star *Asterodiscus truncatus* constitute the first records of this species from Tasmanian waters. The literature pertaining to the species is surveyed briefly and some mention made of specimens held by various institutions.

INTRODUCTION

During 1966-67 three specimens of *Asterodiscus truncatus* were lodged in the collections of the Tasmanian Museum, Hobart. The specimens, all taken off eastern Tasmania are the first records of the species from these waters.

DETAILS OF THE TASMANIAN SPECIMENS

H260 4/6/1966, three miles east of Bicheno, Tasmania, 30 fathoms, Coll. A. J. Harrison. Don. V. V. Hickman.

H261 6/9/1966, five miles north of Diamond Island, near Bicheno, Tasmania, 27-28 fathoms, Don. B. Bosworth.

H294 May 1967, off Bicheno, Tasmania, 40 fathoms, Don. E. R. Guiler.

LITERATURE

Asterodiscus truncatus was recognised as a new species and described by Coleman after H. L. Clark had attributed the "Thetis" specimens to *Nectria ocellifera*. Clark's (1916) report on the "Endeavour" echinoderms mentioned another nine specimens; Serventy's (1937) paper recorded the species at the western end of the Great Australian Bight and Pope (1951) described the colour of the species in life.

Cotton and Godfrey (1942) and Clark (1938 and 1946) reviewed the information then available.

Occurrence of *Asterodiscus truncatus* in New Zealand waters was recorded by Powell (1937).

SPECIMENS

Some 37 registered specimens are lodged in museums in Australia. The holotype and figured paratype are held by the Australian Museum, Sydney (J 1053 and J 2047 respectively). Two specimens (J 6977) collected intertidally and 21 further specimens are also held by that institute.

Five specimens are held by the Museum of Comparative Zoology, Harvard University, including two cotypes (adult from "Thetis" station 56, MCZ 1998: young from "Endeavour" coll. E 1645/MCZ 2484).

COMMENTS

Clark's (1946) comments may now be amended. The species ranges from Norah Head, N.S.W. to the western end of the Great Australian Bight and south to Tasmania; also found in New Zealand waters. The vertical range is from intertidal levels to 200 fathoms.

ACKNOWLEDGMENT

I should like to thank those museums who have allowed me to examine their specimens of *Asterodiscus truncatus*, Miss E. C. Pope for her comments and Dr H. B. Fell for making the M.C.Z. information available to me.

Bibliography

Cotton, B. C. and Godfrey, F. K. (1942)—Echinodermata of the Flindersian Region of South Australia. *Rec. S. Aust. Mus.* VII, 193.

Clark, H. L. 1909).—"Thetis" echinoderms. *Mem. Aust. Hus.* 4, 529.

———— (1916).—Biological Results of the "Endeavour". *Repts. Dept. Trade & Customs: Fisheries, Sydney, N.S.W.* 4, 50.

———— (1938).—Echinoderms from Australia. *Mem. Mus. Comp. Zool.* 55, 101.

———— (1946).—The Echinoderm fauna of Australia. *Publ. Carneg. Instn.* 566, 108.

Coleman, H. L. (1911).—Supplement to Echinodermata. *Mem. Aust. Mus.* 4, 699.

Pope, Elizabeth C. (1951).—Trawlermen's Rubbish. *Aust. Museum Mag.* X (5), 144-149. (cover illustration of species.)

Powell, A. W. B. (1937).—A starfish of the genus *Asterodiscus* new to New Zealand. *Trans. Proc. Roy. Soc. N.Z.*, 67, 78-79, pl. XVI.

Serventy, D. L. (1937).—Zoological notes on a Trawling Cruise in the Great Australian Bight. *Roy. Soc. of West. Aust.*, 23, 81.

DEVELOPMENT AND GROWTH OF THE SOUTHERN ELEPHANT SEAL (MIROUNGA LEONINA) (LINN.)

A review of the literature with some further observations

By

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Communicated by Dr W. Bryden

(With three plates and one text figure)

ABSTRACT

A study of development and growth of the Southern Elephant Seal was carried out at Macquarie Island (54°S, 159°E) while the author was a member of the Australian National Antarctic Research Expeditions, 1964-1966.

HISTORY

Until recently very little was known of the natural history and physiology of the Southern Elephant Seal, although its economic significance has been realised and the species has been exploited commercially since early in the nineteenth century. The inaccessibility of the habitat of the animal has been largely responsible, although relatively little work has been done on the closely related Northern Elephant Seal (*Mirounga angustirostris* (Gill), which is much more accessible. The mass slaughter of elephant seals, both northern and southern species, for their valuable oil in the nineteenth century and the early part of the present century, is well known, and it is thought that the total world population of Northern Elephant Seals may have been as low as 20 during the nineteenth century (Bartholomew and Hubbs, 1960). Apathy, and a general ignorance of the biology of these species, almost caused their complete extinction. It was not until results of a large scale study by Dr R. M. Laws at the Falkland Islands Dependencies in the late 1940's became available that slaughter of elephant seals at South Georgia was put on a sound scientific footing, in order to prevent any repetition of the mass slaughter and decimation of the species which had occurred during the previous century.

Soon after the discovery of Macquarie Island in 1810, sealers began exploiting the elephant seal and in 1826 and 1827 over 1,000 tons of oil were procured (Carrick, 1956). The island was quickly depleted of its stock, breeding cows, young animals, surplus bachelor bulls and breeding bulls being taken. Intermittent killing continued in the same reckless way, and it was after a great deal of publicity concerning the danger of indiscriminate killing of seals, initiated by Sir Douglas Mawson following his journey to Antarctica in 1911-1913, that the Tasmanian Government in 1919 discontinued issuing licences for the killing of elephant seals at the island. The success of this move was soon evident, for, when the "Discovery" called at Macquarie Island in 1930, it was found that large numbers of elephant seals were again breeding there (Mawson, 1932).

The study of the Southern Elephant Seal is difficult due to its inaccessibility, and more importantly to the fact that less than half of its life is spent ashore, where observation is possible. Virtually nothing is known about the life of the animal at sea, and any form of controlled experimentation is difficult due to its amphibious habits.

Two major ecological studies have been made on the species, one by Laws (1953a, 1956a, 1956b) on the Falkland Islands Dependencies populations, the other at Macquarie Island (Carrick and Ingham, 1962a, b and c; Carrick Csordas and Ingham, 1962; Carrick, Csordas, Ingham and Keith, 1962). These major works have expanded and correlated earlier observations performed by a number of other workers (Murphy, 1914; Ring, 1923; Matthews, 1929; Sorenson, 1950; Aretas, 1951; Paulian, 1953, 1957; Angot, 1954; Gibbney, 1953, 1957) and provided the first quantitative data on various aspects of the biology of the Southern Elephant Seal. These studies have rendered the Southern Elephant Seal a well-known animal insofar as its distribution and annual cycle on land, its breeding ecology and physiology, and its numbers are concerned. The detailed study of moulting and the integument of this species made by Ling (1965a, b) has added to our knowledge of the animal.

Some work on the postnatal growth of *Mirounga leonina* has been reported, but it is limited to observations on growth of body length and weight of seals during early postnatal life, and body length changes in later life (Laws, 1953a; Carrick, Csordas and Ingham, 1962). These studies have revealed an interesting and unusual growth pattern in this species. Sivertson (1941) reported a study of growth and changes in gross body composition (blubber and carcass) during early postnatal life in the harp seal (*Phoca groenlandica*), and Scheffer and Wilke (1953) studied relative growth (changes

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in body length, body weight, flipper measurements and skull dimensions with growth) in the Northern Fur Seal, *Callorhinus ursinus*. However, no detailed systematic study of development and growth in the Pinnipedia has been attempted.

REVIEW OF DEVELOPMENT AND GROWTH

Differential growth of the constituent parts of an animal's body has been recognised for centuries as being necessary in order to give rise to the animal's inherent shape. It was known to Xephenon (400 B.C.) and reported by Markham (1617), that one could predict the ultimate size of a horse from the measurement of its shin bone. "For in all quadrupeds the shanks increase but little in size as time goes on, whereas the rest of the body grows to them, so as to be in the right proportion" (Marchant, 1925). Systematic quantitative studies on postnatal development in animals were commenced by Lawes and Gilbert (1859, 1861).

Several authors have proposed definitions of growth and development, each of which has certain advantages and disadvantages. The definitions furnished by Brody (1945) appear adequate for the study of development and growth in the elephant seal. He defined (1) *development* as the directive co-ordination of the diverse processes into an adult—into an "organised heterogeneity" (Needham, 1933); (2) *growth* as biologic synthesis, production of new biochemical units. It is the aspect of development concerned with increase in living substance or protoplasm, and includes one or all of three processes: (i) cell multiplication, (ii) cell enlargement, and (iii) incorporation of material taken from the environment.

The inclusion of non-protoplasmic substances such as fat, blood plasma, cartilage, &c., is an increase by incorporation of material from the environment. Such increase is not regarded as "true growth" by this definition, yet operationally, from the standpoint of quantitative measurement of growth of the organism as a whole we must consider these non-protoplasmic inclusions as parts of the growth process. It is difficult in practice to separate "true growth" and accretion, or increase in amount of non-living structural matter, since the parameter used most in the study of growth is body weight. Elsley, McDonald and Fowler (1964) have pointed out some of the inaccuracies of using total body weight increase as a measure of growth. They showed that fat is a unique tissue with functions very different from those of the other major tissues, and fat deposition is not closely related to the growth of the fat-free body mass. Nalbandov (1963) produced evidence which indicated that reduced growth rate and eventual growth stasis in the growing animal could be attributed to a steady reduction in the amount of available growth hormone per unit of fat-free body weight, but fat deposition was not related to the growth of the fat-free body mass from this point of view.

The use of body weight increase as a measure of growth can never be done away with completely, in spite of the shortcomings, since a vast amount of work is involved to divide the animal body, either by anatomical or biochemical means in the dead animal, or by more recent *in vivo* techniques which have been reviewed by Brozek (1963), Panaretto (1963), and Kirton (1963, 1964), into its component parts.

In some animals, including many aquatic species, certain linear measurements are more useful than body weight to define growth operationally in terms of time relations. The body length is a useful means of estimating growth in terms of chronological time in seals (Scheffer and Wilke, 1953), since body length gives a better indication of body size than does body weight—weight depends on both size and "condition". However any linear measurement can measure growth in only one dimension, whereas it is obvious that growth is three-dimensional, as defined above.

The regular changes which take place in the body composition and conformation of animals during development and growth from birth to maturity were studied by Huxley (1932), who showed that the allometry equation, $y = bx^k$ (where y = size of organ, x = size of rest of body, k = growth coefficient of organ) gave a useful quantitative description of many of these changes. A valuable characteristic of this allometry equation is that it can be transformed into:

$$\text{Log } y = \log b + k \log x$$

to give, generally a straight line. This transformation accentuates the three-dimensional and multiplicative nature of the growth process.

The theory associated with Huxley's formula and its logarithmic transformation implied that the form of an animal depends solely on its absolute size and not on the length of time taken to reach that size. The concept of physiological age (Brody, 1937, 1945) also implies this basic relationship, although in a less direct way. Huxley showed that this relationship applied over a wide range of species and environmental conditions, but pointed out that it may be influenced by some external conditions such as extremes of nutrition and temperature. Severe undernutrition associated with loss of body weight has been shown by Widdowson, Dickerson and McCance (1960), and Wilson and Osbourne (1960), to affect this relationship. Mendes and Waterlow (1958) demonstrated that even when animals were held at an almost constant weight by undernutrition, some growth took place in tissues such as bones and collagen, which have good structural stability. McCance, Ford and Brown (1961) showed that dental development, although delayed by undernutrition, was more closely linked to the animal's chronological age than that of other tissues. Nerve cells in the central nervous system which have already made most of their growth do not regress in size, but the cells in the skeletal muscles do (Widdowson, Dickerson and McCance, 1960).

Extremes of temperature have been shown to affect the relationship, as Huxley predicted. Barnett (1959) observed that mice reared at $-3°C$ reduced their heat loss by developing shorter tails and longer hair. The relationship of tail length to body weight in rats was altered in a hot environment (Harrison, Morton and Weiner, 1959). However, for animals growing on a normal plane of nutrition, Huxley's equation is a most useful

empirical formula for the study of growth gradients (Medawar, 1945; Richards and Kavanagh, 1945; Needham, 1950).

Huxley examined growth gradients in a wide variety of species through application of the allometric equation. His results and those of other workers were reviewed by Palsson (1955), who described a centripetal pattern of postnatal growth. At birth the head, limbs and forequarters are relatively well-developed, the skeleton relatively better developed than the musculature. Developmental changes in the skeleton were attributed to a primary wave of growth beginning at the head and passing down to the nose and lower jaw, and caudally towards the lumbar region; and to a secondary wave from the lower parts of the trunk and limbs ending in the lumbar region. The lumbar region was described as the last part of the body to attain maximum growth rate and was therefore the latest maturing part of the body. Growth in length of the long bones takes place earlier than growth in thickness. A similar centripetal pattern of growth was described for the musculature, but some of the details of this have been challenged by Butterfield and Berg (1966), who showed that although there was evidence of centripetal growth in the limbs of cattle, development did not terminate in the lumbar region. Differential growth also occurs in the major tissues and organs which attain their maximum rate of growth in a definite order with age: broadly, nervous tissue, bone, muscle and fat. Allometric growth of individual organs appears to be primarily functional: brain, eyes, kidneys and heart, for example, being early maturing organs. Those organs of most physiological significance to the animal are relatively well developed at birth, as distinct from those organs which have little functional importance until some time after birth.

Most mammals on which detailed systematic growth and development studies have been made have been domestic species. Growth and development have been studied in several wild mammalian species, but most of these studies have only involved body weight changes where possible, and more often, external changes in form in terms of linear measurements, and have not considered the relative growth of the body tissues and organs. A problem met with in studying growth in many wild species is the absence of any reliable method of ageing.

EXPERIMENTAL

(a) Introduction

A systematic study of development and growth of *Mirounga leonina* was attempted, on the assumption that such a study might reveal interesting comparisons with growth and developmental patterns in other mammals. The mammals on which detailed studies of this nature have been made exhibit external forms and ecological patterns markedly different from those of the seal. It was felt that the unusual pattern of postnatal growth in the elephant seal could possibly provide details of some facets of the growth process not revealed by studies of growth in domestic mammals, and clarify some of the hitherto misunderstood aspects of mammalian growth. In particular it was considered that the period of accelerated growth which is known to occur soon after birth (Laws, 1953a; Carrick, Csordas and Ingham, 1962) may be illuminating due to the exaggeration of all the physiological processes involved with growth at this time.

In planning the present study, knowledge of the seasonal movements of the Southern Elephant Seal at Macquarie Island furnished by Carrick, Csordas, Ingham and Keith (1962) was invaluable. Immediately after birth the elephant seal undergoes a 23-day suckling period on land, during which time growth is extremely rapid (see Plate 1), followed by a five- to seven-week postweaning fast while the animal becomes adapted for a life at sea. After the attainment of nutritional independence, individuals spend most of their lives at sea, but from time to time they haul out on land where they undergo a complete fast lasting up to two months, and suffer dramatic body weight losses in some instances. Following puberty, a very marked discrepancy in size develops between males and females (Plate 2).

(b) Materials and Methods

A description of the anatomical methods used in, and the results obtained from, this work have been submitted for publication elsewhere (Bryden, 1967a). In brief, seals of both sexes from birth to maturity were dissected anatomically into skin, fat and connective tissue, and individual muscles, bones and organs. A total of 96 animals was dissected.

Seals could only be studied during their periods on land, and the numbers of animals of the different age groups ashore at Macquarie Island during the year are illustrated in Figure 1. Growth was studied in most detail during the early postnatal period, from birth of the pup to the time of its departure to the sea, which meant that a very large portion of the work was concentrated in the breeding season, from mid-September to mid-November, 1965; adult females were studied during their annual moult period in January and February; immature seals of both sexes were studied from April to August when they appeared at the island for winter "rest periods"; and breeding bulls ashore for the breeding season were studied during the latter half of August and the first half of September, up to the beginning of the breeding season.

Foetal growth was not considered in any detail in this study owing to the lack of material. Pregnant females spend the entire gestation following implantation of the blastocyst at sea, and only the occasional straggler returns to land during winter. An attempt was made to keep six pregnant females in captivity during the winter months in a large enclosure in which a swimming tank was provided (Plate 3), but the many hours spent on attempts at feeding the animals were unfruitful. Suggestions for encouragement of feeding this and closely related species (Bullier, 1954; Pournelle, 1962 and personal communication) were observed, but with no success. Subsequent discussions with Dr C. R. Schroeder, Director of the San Diego Zoo, California, U.S.A., have revealed that for all practical purposes, it is impossible to train adult elephant seals to eat in

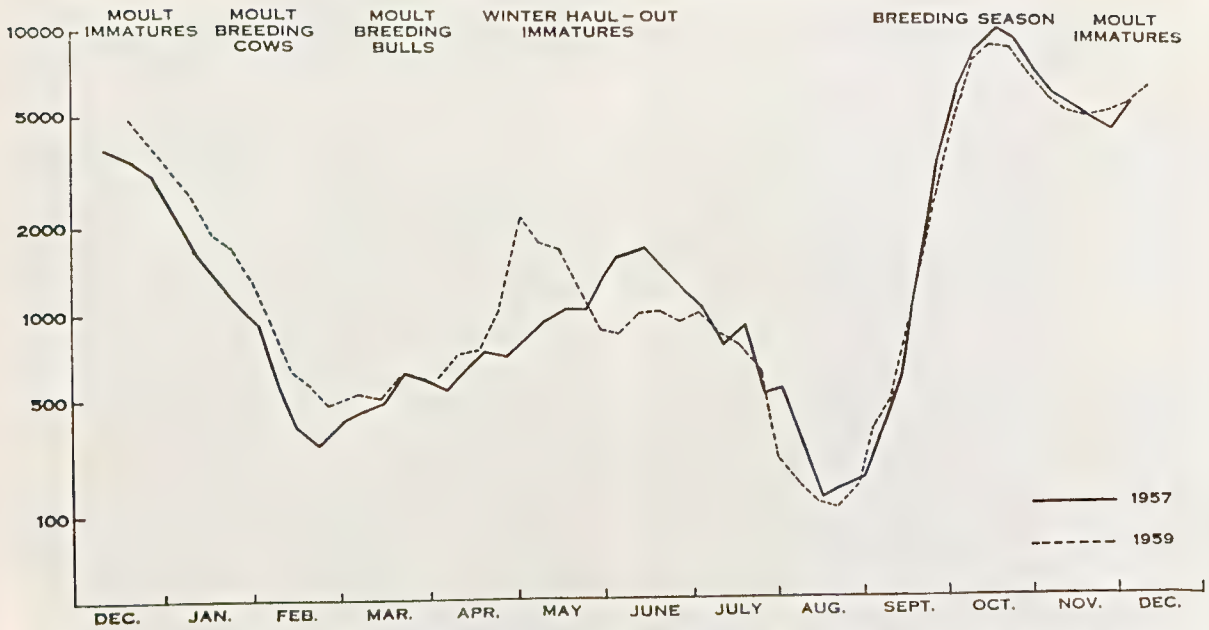

FIG. 1.—Total number of elephant seals in the Isthmus Study area, Macquarie Island, each week during 1957 and 1959 (from Carrick, Csordas and Ingham, 1962).

captivity. All of the elephant seals (*Mirounga angustirostris*) which have been kept successfully at the San Diego Zoo have been introduced at an immature stage, and the most successful have been recently-weaned pups.

Measurements of six elephant seal foetuses collected at Macquarie Island in 1956 by Mr K. Keith were kindly made available by Dr R. Carrick, Mawson Institute for Antarctic Research, Adelaide, and measurements of these plus the one foetus collected in 1965, were included in this study as they were the only foetal measurements available to the author.

(c) Results and Discussion

Development and growth of the elephant seal were considered along two main channels of thought, first the aspects of development (which, by the definition given earlier, includes growth) associated with the ecology of the species, and secondly the changes in form which are similar to those in other animals.

The ecology of the species, so very different from that of other mammalian species on which detailed studies of development have been made, has resulted in alterations to many of the postnatal developmental processes within the body and has exaggerated some of the physiological mechanisms associated with development. Brody (1945) stated "aquatic animals are not forced to change much in form with increasing weight because their weight is counterpoised by the displaced water". This statement was based on earlier observations of Hecht (see Jackson, 1928) in fish, whose form was shown to change little with increasing weight, and whose ultimate size was not an important factor in the growth process. The form of the elephant seal must alter with increasing weight because, although most of its life is spent at sea, it is still subjected to the effects of gravity during its haul-out times. This study has revealed that the control of ultimate size in the elephant seal is of great importance, particularly in the male (which is very much larger than the female), due to the periodic influence of gravity during times when animals are ashore (Bryden, 1967b). Thus it differs from a totally aquatic mammalian group such as the whales, whose development does not need to allow for the effects of gravity.

The change in form of the elephant seal during growth is quite marked, and was illustrated by a quotation of Charles Eyre, cited by Sorenson (1950): "Over a big hill which separated us from the next bay some of the party had seen, the previous day, a huge sea-elephant . . . The first thing which caught our eye when we reached the bay was a small seal of the sort I had never seen before. Its eyes were about the size of a five-shilling piece and something awful to look at". The latter was later identified as a young elephant seal. The early development of the eyes of the elephant seal is very obvious, as this observation illustrates, and in this and certain respects differential growth in this species is similar to other mammals studied. However in other respects the pattern of differential growth has been shown to be different from domestic mammals. For example, postnatal development of the subcutaneous fat in the elephant seal occurs much earlier than does the fat in terrestrial mammals; considerable relative post-

natal growth of the blood occurs in the seal, and relative growth within the muscular and skeletal systems in elephant seals, showing patterns different from those in domestic mammals, occurs. Details of these observations have been submitted for publication elsewhere (Bryden, 1967a).

In an anatomical study of this kind, in which animals were dissected and measured at different stages of postnatal growth, it is clearly impossible to take measurements on the same animal at different stages of growth. In similar studies with other animals, it has been possible to utilise identical twins (Bonnier and Hansson, 1945-46; Walker, 1961; Taylor, 1958, 1962) or littermates (Cuthbertson and Pomeroy, 1962) in order to minimise the errors involved by comparing different animals at successive stages of growth. This is virtually impossible in any wild species since one cannot be certain of recapturing any particular animal after it becomes nutritionally independent. Multiple births are extremely rare in the elephant seal (Bryden, 1966), which rendered impossible the use of closely related seals, even at the suckling stage. The only means of overcoming these difficulties was to use a large number of animals, which made time the limiting factor. Sufficient numbers of animals were dissected to study developmental changes during early postnatal growth, before the establishment of nutritional independence, in considerable detail, but further dissections of animals during the time of life at sea are required to gauge more accurately the differential changes which take place in the body during this phase of growth. In particular, a more detailed study of the developmental changes in the male just before and just after it reaches sexual maturity would reveal more clearly changes which have been only briefly dealt with in the present work.

One of the difficulties involved with a study of this nature is that one has no means of knowing whether immature animals which haul-out during winter are truly representative of their age group. Possibly only the smaller, weaker seals haul-out at this time, or it could be that the more dominant animals which do not have to travel so far from land to feed successfully are the ones seen resting on the beaches. However the shapes of the growth curves, which exhibit the characteristic sigmoid shape (see Carrick, Csordas and Ingham, 1962), indicate that animals of the earlier age groups, most of them measured during winter haul-out, are representative of their respective age groups. The uncertainty again exists with foetuses, whether these foetuses are representative of growth of the elephant seal foetus at a particular stage, or whether only weak cows, with retarded foetuses, haul-out during the winter. However this is not likely to have affected most of the foetuses considered in this work, in the light of the observations of Barcroft (1946), who states that environmental retardation does not occur in the foetus until during the final quarter, or less, of pregnancy. All but one of the elephant seal foetuses were at an earlier stage than that.

As opposed to the several difficulties encountered, studies on the elephant seal have several advantages. First, the animals are very tractable and easy to handle on land. Secondly, there are relatively few hauling-out places around the Southern Ocean, so the chances of a marked animal returning to a part of the small area of coastline of Macquarie Island are high. Thirdly, animals can be aged with a considerable degree of accuracy as a result of the findings of Laws (1953b) and Carrick and Ingham (1962b).

By selecting the elephant seal as an experimental mammal in which growth processes are exaggerated during early postnatal life and are modified due to the marked alteration of environment when the animal goes to sea, it has been possible to study some aspects of growth in detail, which have been obscure up to the present time.

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References

Angot, M. (1954).—Observations sur les mummifères marins de L'Archipel de Kerguelen, avec une étude detaillée de l'éléphant de mer, *Mirounga leonina* (L.) *Mammalia* 18: 1-111.

Aretas, R. (1951).—L'éléphant de mer (*Mirounga leonina* Linn.)—Etude biologique de l'espèce dans les possessions francaises Australes (Archip. de Kerguelen). *Mammalia* 15: 105-117.

Barcroft, J. (1946).—*Researches on Prenatal Life.* (Oxford: Blackwell).

Barnett, S. A. (1959).—Skin and hair of mice living at a low environmental temperature. *Quart. J. exp. Physiol.* 44: 35-42.

Bartholomew, G. A. and Hubbs, C. L. (1960).—Population growth and seasonal movements of the Northern Elephant Seal, *Mirounga angustirostris. Mammalia* 24: 313-324.

Bonnier, G. and Hansson, A. (1945-46).—Studies on monozygous cattle twins. V. The effect of different planes of nutrition on growth and development of dairy heifers. *Acta Agric. Suec* (*Stockh.*) 1: 171-205.

Brody, S. (1937).—Relativity of physiologic time and physiologic weight. *Growth* 1: 60-123.

———— (1945).—*Bioenergetics and Growth.* (New York: Reinhold).

Brozek, J. (Ed. 1963).—Body composition. *Ann. N.Y. Acad. Sci.* 110: 1-1018.

Bryden, M. M. (1966).—Twin foetuses in the Southern Elephant Seal, *Mirounga leonina* (L.). *Papers Proc. Roy Soc. Tas.* 100: 92-93.

———— (1968a).—Growth and development of the Southern Elephant Seal, *Mirounga leonina* (L.) . I to VII. *Aust. J. Biol. Sci.* (In press).

———— (1968b).—Theoretical consideration of the control of growth in two populations of elephant seals (*Mirounga leonina*, L.). *Nature.* (In press).

Bullier, P. (1954).—Alimentation et acclimatement d'éléphants de mer (*Mirounga leonina* L.) en captivité, au parc zoologique du Bois de Vincennes. *Mammalia* 18: 272-276.

Butterfield, R. M. and Berg, R. T. (1966).—Relative growth patterns of commercially important muscle groups of cattle. *Res. Vet. Sci.* 7: 389-393.

Carrick, R. (1956).—The wildlife of Macquarie Island. *Aust. Mus. Mag.* 12: 255-260.

CARRICK, R. and INGHAM, S. E. (1962a).—Studies on the Southern Elephant Seal, *Mirounga leonina* (L.).—I. Introduction to the series. *C.S.I.R.O. Wildl. Res.* 7: 89-101.

——————— (1962b).—Studies on the Southern Elephant Seal, *Mirounga leonina* (L.).—II. Canine tooth structure in relation to function and age determination. *C.S.I.R.O. Wildl. Res.* 7: 102-118.

——————— (1962c).—Studies on the Southern Elephant Seal *Mirounga leonina* (L.).—V. Population dynamics and utilisation. *C.S.I.R.O. Wildl. Res.* 7: 198-206.

———————, CSORDAS, S. E. and INGHAM, S. E. (1962).—Studies on the Southern Elephant Seal, *Mirounga leonina* (L.).—IV. Breeding and development. *C.S.I.R.O. Wildl. Res.* 7: 161-197.

———————, INGHAM, S E. and KEITH, K. (1962).—Studies on the Southern Elephant Seal, *Mirounga leonina* (L.).—III. The annual cycle in relation to age and sex. *C.S.I.R.O. Wildl. Res.* 7: 119-160.

CUTHBERTSON, A. and POMEROY, R. W. (1962).—Quantitative anatomical studies of the composition of the pig at 50, 68 and 92 kg carcass weight.—I. Experimental material and methods. *J. Agri. Sci.* 59: 207-214.

ELSLEY, F. W. H., MCDONALD, I. and FOWLER, V. R. (1964).—The effect of plane of nutrition on the carcasses of pigs and lambs when variations in fat content are excluded. *Anim. Prod.* 6: 141-154.

GIBBNEY, L. F. (1953).—Delayed implantation in the elephant seal. *Nature, Lond.* 172: 590.

——————— (1957).—The seasonal reproductive cycle of the female elephant seal—*Mirounga leonina* (L.)—at Heard Island. *A.N.A.R.E. Rep.* (B) 1: 1-26.

HUXLEY, J. S. (1932).—*Problems of Relative Growth.* 1st Ed. (London: Methuen).

JACKSON, C. M. (1928).—Some aspects of form and growth. In Robins, W. J., Brody, S., Jackson, C. M., Hogan, A. G. and Green, C. W.—*Growth.* (New Haven: Yale Press).

KIRTON, A. H. (1963).—Some relations between the potassium and sodium contents of animals and their composition. Sect. 3, pp. 1-18. In *Selected Papers of Aust C.S.I.R.O. Symp. on Carcase Composition and Appraisal of Meat Animals.* (Melbourne: C.S.I.R.O.).

——————— (1964).—Assessment of body composition in the live animal. *Proc. N.Z. Soc. Anim. Prod.* 24: 77-89.

LAWES, J. B. and GILBERT, J. H. (1859).—Experimental enquiry into the composition of some of the animals fed and slaughtered as human food. *Philos. Trans.* 2: 494-680.

——————— (1861).—On the composition of oxen, sheep and pigs and of their increase whilst fattening. *J.R. Agric. Soc.* 21: 433-488.

LAWS, R. M. (1953a).—The elephant seal (*Mirounga leonina*, Linn.). I. Growth and age. *F.I.D.S. Scientif. Rep.* 8: 1-62.

——————— (1953b).—A new method of age determination in mammals with special reference to the elephant seal (*Mirounga leonina, Linn.*). *F.I.D.S. Scientif. Rep.* 2: 1-11.

——————— (1956a).—The elephant seal (*Mirounga leonina*, Linn.). II. General, social and reproductive behaviour. *F.I.D.S. Scientif. Rep.* 13: 1-88.

——————— (1956b).—The elephant seal (*Mirounga leonina*, Linn.). III. Physiology of reproduction. *F.I.D.S. Scientif. Rep.* 15: 1-66.

LING, J. K. (1965a).—The integument and moulting process of the Southern Elephant Seal, *Mirounga leonina* (Linn.). Ph. D. Thesis, Australian National University.

——————— (1965b).—Hair growth and moulting in the Southern Elephant Seal, *Mirounga leonina* (Linn.). In *Biology of the Skin and Hair Growth.* Ed. Lyne, A. G. and Short, B. F. (New York: American Elsevier Publ. Co.).

MCCANCE, R. A., FORD, E. H. R. and BROWN, W. A. B. (1961).—Severe undernutrition in growing and adult animals. 7. Development of the skull, jaws and teeth in pigs. *Brit. J. Nutr.* 15: 213-224.

MARCHANT, E. C. (1925).—*Xephenon: scripta minora.* English translation: Loeb Classical Library. (London: Heineman).

MARKHAM, G. (1617).—Cavalarice; Book 1, Chap. 14. Cited by McCance, R. A. (1962)—Food, growth and time. *Lancet,* ii, 621-626.

MATTHEWS, L. H. (1929).—The natural history of the elephant seal, with notes on other seals found at South Georgia. *'Discovery' Rep.* 1: 233-256.

MAWSON, D. (1932).—The B.A.N.Z. Antarctic Research Expedition, 1929-1931. *Geograph. J.* 80: No. 2.

MEDAWAR, P. B. (1945).—Size, shape and age. In *Essays on Growth and Form.* Ed. le Gros Clark, W. E. and Medawar, P. B. (Oxford: Clarendon Press).

MENDES, C. B. and WATERLOW, J. C. (1958).—The effect of a low protein diet, and of refeeding, on the composition of liver and muscle in the weanling rat. *Brit. J. Nutr.* 12: 74-88.

MURPHY, R. C. (1914).—Notes on the sea elephant, *Mirounga Leonina* (Linné). *Bull. Am. Mus. Nat. Hist.* 33: 63-79.

NALBANDOV, A. V. (1963).—Symposium on growth: endocrine causes of growth and growth stasis. *J. Anim. Sci.* 22: 558-560.

NEEDHAM, A. E. (1950).—The form transformation of the abdomen of the female pea crab, *Pinnotheres pisum. Proc. Roy. Soc.* B, 137: 115-136.

PALSSON, H. (1955).—Conformation and body composition. In *Progress in the Physiology of Farm Animals.* (London: Butterworths).

PANARETTO, B. A. (1963).—The estimation of body composition in living animals. In *Selected Papers of Aust. C.S.I.R.O. Symp. on Carcase Composition and Appraisal of Meat Animals.* (Melbourne: C.S.I.R.O.).

PAULIAN, P. (1953).—Pinnipèdes, cétacés, oiseaux des Iles Kerguelen et Amsterdam. *Mem Inst. Sci. Madagascar* 8: 111-234.

——————— (1957).—Note sur les phoques des Iles Amsterdam et Saint-Paul. *Mammalia* 21: 210-215.

POURNELLE, G. H. (1962).—The Northern Elephant Seal, *Mirounga angustirostris,* Gill, in the San Diego Zoo. *Internat. Zoo Handbook* 4: 32-33.

RICHARDS, O. W. and KAVANAGH, A. J. (1945).—The analysis of growing form. In *Essays on Growth and Form.* Ed. leGros Clark, W. E. and Medawar, P. B. (Oxford: Clarendon Press).

RING, T. P. A. (1923).—The elephant seals of Kerguelen Land. *Proc. Zool. Soc. Lond.,* 431-433.

SCHEFFER, V. B. and WILKE, F. (1953).—Relative growth in the Northern Fur Seal. *Growth* 17: 129-145.

SIVERTSON, E. (1941).—On the biology of the harp seal, *Phoca groenlandica,* Erxl. *Hvalradets Skrifter, Oslo,* No. 26: ix + 166 pp.

SORENSEN, J. H. (1950).—Elephant seals of Campbell Island. *Cape Exped. Ser. Bull.* No. 6: 1-31.

TAYLOR, ST C. S. (1958).—A linear growth process in twin cattle. *Proc. 10th Int. Congr. Genet.* 2: 291A.

——————— (1962).—Identical twins and developmental stability. *Anim. Prod.* 4: 144-164.

WALKER, D. E. (1961).—A study of the growth and development of Jersey cattle. I. A new carcass dissection technique. *N.Z. J. Agric. Res.* 5: 190-222.

WIDDOWSON, E. M., DICKERSON, J. W. T. and MCCANCE, R. A. (1960).—Severe undernutrition in growing and adult animals. 4. The impact of severe undernutrition on the chemical composition of the soft tissues of the pig. *Brit. J. Nutr.* 14: 457-471.

WILSON, P. N. and OSBOURNE, D. F. (1960).—Compensatory growth after undernutrition in mammals and birds. *Biol. Rev.* 35: 324-363.

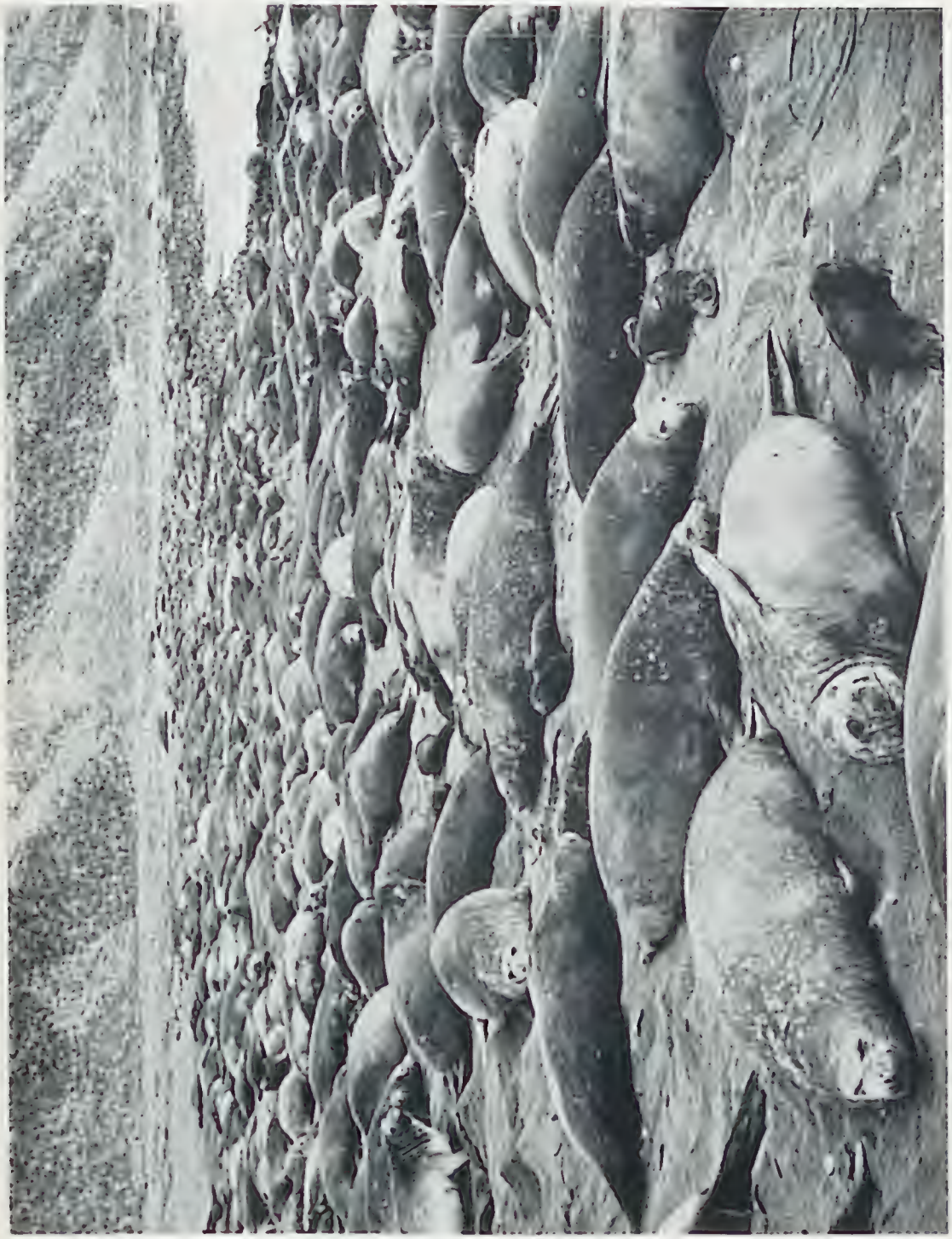

Plate 1.—The relative size of cows and pups changes rapidly during growth of the pup, as can be seen here. Some pups are very much smaller than their mothers, whereas others appear to be almost as large as their mothers.

Plate 2.—Relative size of a mature male and a mature female elephant seal at Macquarie Island. The male is approximately eight times as heavy as the female.

Plate 3.—Enclosure and swimming tank for elephant seals at Macquarie Island. Photograph is taken through opened doors.

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THE GEOLOGY OF THE KINGSTON AREA

By

Gillian C. Paxton

University of Tasmania

(With five text figures and one plate)

ABSTRACT

In the Kingston-Blackmans Bay area, flatly dipping Permian marine sediments ranging in age from the Quamby Group (Upper Sakmarian) to the Ferntree Mudstone (Kazanian) are overlain, with slight angular discordance, by terrestrial Triassic sandstone. The sedimentary rocks have been intruded by Jurassic dolerite in the form of sills and transgressive sheets. Tertiary faulting, producing an approximately north-south parallelism of large-scale structures, preceded volcanic activity in which basalt flows covered much of the area.

INTRODUCTION

The area mapped lies between Bonnet Hill to the north and Flowerpot Point to the south and extends westwards from the coast as far as the powerline which supplies power to the Electrona Carbide Works. This area of approximately 10 square miles includes the townships of Kingston, Kingston Beach and Blackmans Bay. Soil types have been mapped by Loveday (1955).

Lithological boundaries were mapped onto aerial photographs in the field, then transferred to a 1000 feet to the inch base map produced by the Southern Metropolitan Master Planning Authority in 1958. Outcrop is good in cliff sections along the coast, but inland it is very poor.

The author thanks the staff of the Geology Department, especially Mr M. R. Banks, for helpful discussion and assistance in mineral and fossil identifications. Valuable help was given by B. Palmer, A. Hinch, G. Loftus-Hills and M. Sugden with field work.

PHYSIOGRAPHY

Relief is largely controlled by lithology (see Fig. 1). To the west, hills composed of Permian sediments intruded by Jurassic dolerite rise to 900 feet. Bonnet Hill, capped by resistant dolerite, rises steeply to a height of 700 feet within 1¼ miles from the coast. This terrain contrasts with the undulating sandy hills on Triassic sandstone and the gentle hill slopes produced by basalt flows.

The coastline, consisting of steep cliffs of Permian sediments, broken by resistant dolerite headlands and two gently curved beaches, is controlled by the Tertiary fault pattern which is responsible for the Derwent Graben (Banks, 1958a). Lithology and the dominant directions of faults and joints allow the formation of sea caves, pebble beaches, a small stack on Flowerpot Point, the Blackmans Bay Blowhole and approximately horizontal rock platforms twenty to thirty feet wide.

Drainage is related to faults and lithological boundaries (see Fig. 1), and to the permeability of the underlying rocks (Farmer, 1963). Streams flow either east to Kingston Beach, often as tributaries to Browns River, or into North-West Bay. Mountain tract streams flowing east from Bonnet Hill are deep and steep-sided and end as small, cliff waterfalls on the coast.

STRATIGRAPHY

Permian System

Lower Permian Sediments

The oldest rock identified in the area outcrops along the Margate Road opposite the Howden Road turnoff. It contains *Pseudosyrinx*, a fossil which suggests correlation with the top of the Quamby Group or lower part of the Golden Valley Group (Upper Sakmarian). Other fossils identified from this locality are *Eurydesma cordatum* (sp. 85018)*, *Keeneia twelvetreesi* (sp. 85016), *Astartila pusilla* (sp. 85019), *Stenopora johstoni, Calcitornella* and *Grantonia* n. sp. (sp. 89154). *Peruvispira elegans, Keeneia* ? *ocula* and *Astartila* cf. *pusilla* were found in the first road cutting north of the Howden Road turnoff (see sp. 89161). The rock is a mudstone with irregular bands up to 1 m. thick of dark greenish grey, less fossiliferous siltstone in the lower parts of the section.

Between the latter rocks and the overlying Grange Mudstone occur approximately 100 m. of fossiliferous, marine sandstones and siltstones. Outcrop is poor and accurate thicknesses cannot be obtained. The sequence includes fenestellid siltstones; siltstones containing numerous marine fossils such as *Stenopora* and *Strophalosia;* a fine sandstone very rich in ostracodes with foraminifera (e.g., *Frondicularia*) and fragments of brachiopods; and a siltstone containing pelecypods (spp. 85020, 85022). A *Strophalosia* species also present in the Lewis Point Siltstone, the Brumby Marl, the Darlington Limestone and the Golden Valley Group (all Lower Permian), was found on the hill 30 m. above the Howden Road turnoff. *Stenopora crinita* (sp. 85020); *Schuchertella* (sp. 85021); *Peruvispira trifilata* (sp. 85023); *Stophalosia* n. sp. and a fragment probably of *Aviculopecten tenuicollis* (sp. 89156); *Protoretepora ampla, Ingelarella* cf. *ingelarensis, 'Spirifer' convolutus, Gilledia ulladullensis, Streblopteria* sp., *Astartila* n. sp. cf. *pusilla* and *Camptocrinus* sp. (sp. 89157), were also present at this locality. Although these individual fossils are not stratigraphically significant, the fossil suite is

* Numbers refer to specimens in the collection of the Geology Department, University of Tasmania.

characteristic of the Branxton Sub-group of New South Wales.

The Lower Permian section appears to be unfaulted and to conformably underlie the Grange Mudstone. It should therefore correspond to the Faulkner Group. However, the Faulkner Group in the Hobart area, for example at Porters Hill, is deltaic, whereas these sediments are marine. At Snug the Snug Mudstone is thought to be a marine equivalent of the Mersey Group, to which the Faulkner Group belongs (Banks, 1962a, p. 205). Thus it is probable that the shoreline at the time of deposition of the Faulkner Group was between Hobart and Kingston.

A belt of very poorly exposed sediments north of Parks Hill and west of the North-West Bay Fault have been tentatively mapped as Lower Permian. However, recent palaeontologic and stratigraphic work by the Department of Mines in Hobart indicates that this is part of the Malbina Formation.

Grange Mudstone

The Grange Mudstone is over 60 m. thick. The exact thickness at Kingston cannot be deduced due to a fault between the exposure of the basal beds and the top of the most complete section—that on Parks Hill—where a block of Grange Mudstone has been uplifted by the Jurassic dolerite. Although an attempt was made to measure a section along the track from (5127, 7071) to (5133, 7066) exposure is not sufficient for this measurement to show up more than gross differences along the saddle. Because of these differences a fault has been postulated which passes up the valley in a roughly north-south direction.

The name 'Grange Mudstone' seems unsuitable here where the succession includes several sandgrade beds, especially near the top. The name 'Grange Formation' would be more suitable. To illustrate this point, the main features of the 16 m. section measured to the west of (5128, 7071) on Parks Hill will be described below.

The basal 3 m. consists of a coarse, very poorly sorted rock containing 20-30% of quartzitic rock fragments up to 4 cm. long and some mica flakes ($< 1\%$), (sp. 847). The matrix (70%) is a fine sand with an average sphericity of 0.7 and roundness of 0.3 (Krumbein and Sloss, 1958, p. 81). The rock is poorly bedded and jointed and is fairly brittle. The only fossils seen were a few fenestellids near the base. Overlying this unit is approximately 12 m. of a fairly well-sorted yellowish grey siltstone (sp. 843) containing $< 1\%$ mica and quartz grains and usually $< 1\%$ rock fragments (mainly quartzite). Parallel bands of polyzoans (especially fenestellids), give an impression of bedding. Sphericity to roundness ratio (S/R) is 0.7/0.3. This rock is interbedded with bands of coarser sediment which, in general, become thicker and coarser lower in the section. Specimen 845, from a coarse-grained band 20 cms. thick at a height of 6.75m. in the section, is a poorly fossiliferous, fine-grained sand, very hard and fairly well-sorted. One metre below the top of the section is a band of poorly sorted, medium light grey sand (sp. 844), containing angular quartz and fossil fragments. The upper part of the section consists of a thin band of fine sandstone, probably belonging to the Malbina Formation.

Although the western Parks Hill section is atypical of the Grange Mudstone it is correlated with this formation for the following reasons:—Sandstone and fine granule conglomerates near the top of the Grange sequence have been reported from South Arm by Green (1961); although on Parks Hill the sandstone beds are lithologically similar to those of the Malbina Formation, they are interbedded with Grange-type fenestellid-rich siltstone; the fossil assemblage is characteristic of the Grange Mudstone.

On the hill to the east of (5128, 7071) a section much more similar to the usual Grange Mudstone is exposed. The characteristic rock is a yellowish grey siltstone with some calcareous fossil fragments and a cherty appearance, presumably due to metamorphism by underlying Jurassic dolerite. Many beds are composed mainly of shell fragments, often concentrated near the top of the bed (e.g., sp. 849). Quartz grains and a few mica flakes (both up to 5 mm. long) are present. In contrast to the western section, some pectens (including *Aviculopecten tenuicollis* and *Deltopecten subquinquelineatus*, sp. 89158) are found. Fenestellids are common and again are concentrated in layers. Fossils are less abundant in the lower parts of the section.

Malbina Siltstone and Sandstone

There is little outcrop of the Malbina Formation in the area which was mapped. The small section of this formation on Parks Hill (5127, 7071) is a poorly-sorted, fine sandstone containing mica grains and quartzite fragments (sp. 855). The sand grains are sub-angular with a fairly high sphericity. (S/R $= 0.7/0.5$).

Risdon Sandstone

No Risdon Sandstone was found in the area, but to the north of the cliffs below Taronga it outcrops as a sandstone formation 3 to 4 m. thick which overlies the Malbina Formation and underlies the Ferntree Mudstone. In weathering features and general appearance this rock (e.g., sp. 857) is similar to the Triassic sandstones. However, it can be distinguished by its small thickness, stratigraphic position and poor sorting.

Ferntree Mudstone

The Ferntree Mudstone is overlain by Triassic sandstone. Below Taronga it is underlain by the Risdon Sandstone, but the base of the Ferntree Mudstone is not exposed at Kingston. The thickness of the type section at Ferntree is about 185 m. As in the case of the Grange Mudstone, the Ferntree Mudstone should be called the Ferntree *Formation* as it contains sandstones and conglomerates. Because the mudstone at Kingston contains conglomerate beds, many erratics and possible turbidity current deposits, some manuscript maps show it as the Malbina Formation, overlain by the Risdon Sandstone. Evidence is strong that it is, in fact, equivalent to the Ferntree Mudstone as suggested by Lewis (1946, p. 141) and is overlain by Triassic sandstone. Firstly, it underlies sandstone—of which the thickness, good-sorting and

siliceous nature indicate a Triassic age—with slight angular discordance. Secondly, the abundantly fossiliferous horizons found elsewhere at the top of the Malbina Formation (e.g., at Taronga) have not been found here but a band of marine fossils occurs about 30 m. below the top. These are rather poorly preserved large pelecypods, probable plant fragments and *Peruvispira* (sp. 85023). *Myonia carinata*, found near the top of the section and in Member E of the Malbina Formation, has been reported by Woolley (1959) from the Ferntree Mudstone near New Norfolk in which sandstones and beds with numerous erratics up to several inches long also occur. Thirdly, worm tubes, animal burrows and fan-like markings on bedding planes are very common and pyrite nodules are found. These are all characteristic of the Ferntree Mudstone.

If this *is* Malbina Formation, the Ferntree Mudstone is absent between it and the Triassic sandstone. Then either: after deposition of the Malbina Formation this area was an uplifted block on which Ferntree Mudstone was not deposited; or up to 185 m. of Ferntree Mudstone were removed by erosion before deposition in the Triassic; or there has been unusual faulting along the coast. This last explanation seems unlikely because if the base of the overlying sandstone is plotted using a dip of 5° and measured strikes, it coincides with the contacts found in the field. It seems, then, that the simplest and most plausible explanation is that this section is equivalent to the Ferntree Mudstone.

The coastal outcrop of Ferntree Mudstone consists, in general, of well-bedded and well-jointed fine sandstone alternating with narrower, more fissile siltstone beds. The fine sandstone beds are 0.3 to 1.5 m. thick. A 13 m. vertical section was measured along the cliffs south of Boronia Point (see Fig. 2 and appendix). Some interesting features are revealed in this section.

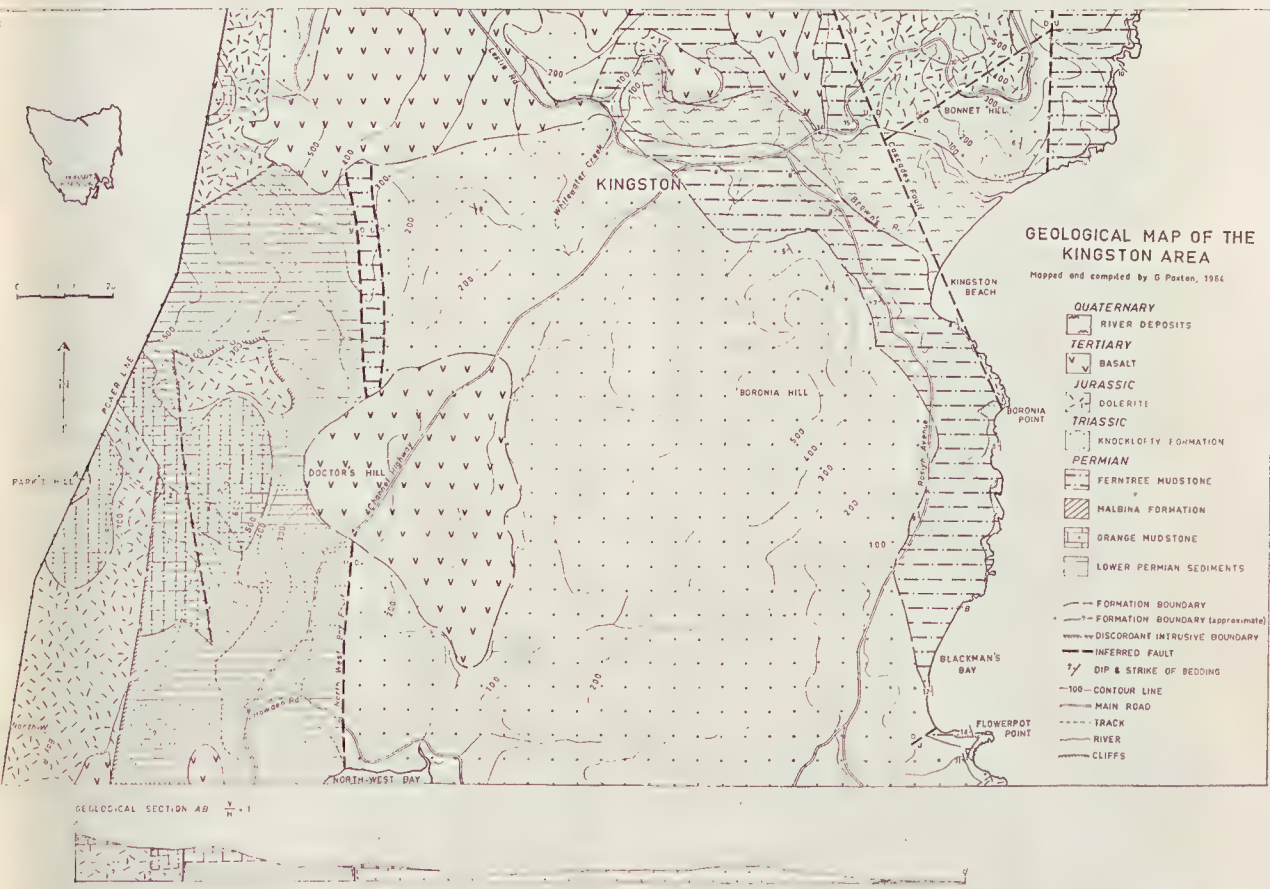


FIG. 1

1. Animal burrows are present throughout. Near the top they occur in fine, black, fissile beds which alternate with harder, fine sandstones. They usually project downwards from the surface of the bed. Near the top of the section the burrows are in the form of sandy cylinders 1-2 cm. in diameter and up to 5 cm. long. The material contained within the cylinders is much coarser-grained and less well-sorted than the surrounding sediment (sp. 906). They may be worm or pelecypod burrows, although no pelecypods were found in them. In the lower part of the section the burrows occur at the surfaces of successive beds. They are very much more numerous than above, of a finer material and with a regular, dumb-bell shaped cross section (Plate 1, Figs. 1 and 2).
2. There is a band of large, oval, concretions in Unit H (see appendix). The concretions are up to $\frac{3}{4}$ m. long and $\frac{1}{2}$ m. wide. Some are double. They were formed *in situ* because one sampled contains angular erratics similar to those in the surrounding rock. The bed below appears to have been bowed down slightly by the growth of the concretion (Plate 1, Fig. 3). Unfortunately the concretionary rock is very porous due to leaching of the constituent minerals which suggests that it contained carbonate—either siderite or calcite. Siderite is more probable because the concretions are surrounded by a narrow limonitic rim.
3. Erratics are very numerous in the Ferntree Mudstone. They are mainly quartzite, but shale, mica schist, sandstone and a porphyrite have also been found. The porpryrite erratic (sp. 866) is approximately 10 cms. in diameter, contains quartz and orthoclase and is similar in texture to the St Marys Porphyrite (sp. 4652). However, sp. 4652 contains plagioclase and biotite as well as quartz as phenocrysts. If the erratic is of St Marys Porphyrite, it may indicate movement of icebergs from the north-east. Many of the erratics found in the Ferntree Mudstone, especially the larger ones, are probably ice-rafted. North of Kingston Beach there are numerous angular erratics of sandstone and quartzite, $\frac{1}{4}$ cm. to 10 cm. long, which often have a vertical long axis and bend the laminations in fine-grained beds. However, in the measured section there are beds of pebbles, up to 12 cms. long. The long axes are usually horizontal and the sphericity and roundness are very varied. The origin of these will be discussed below.

There is strong evidence for deposition by swiftly moving muddy currents. On Flowerpot Point, at the south end of Blackmans Bay and about 30 m. below the base of the Triassic sandstone, are two conglomerate bands, approximately 15 cms. thick and 0.5 m. apart (sp. 861). The rock is grey and very friable containing fragments from 1 mm. to 5 cm. long in a clay-grade matrix. The framework is open. The clastic fragments are generally in two grainsize ranges, 1-2 mm. and about 5 mm. Roundness varies from 0.1 to 0.7 and sphericity from 0.5 to 0.9. The smaller grainsize fraction is composed mainly of quartzite fragments which have an average sphericity to roundness ratio of 0.7/0.3. The larger grainsize fraction is composed of shale and sandstone fragments from 0.5 to 5 cm. in length. $S/R = \frac{0.5—0.7}{0.1}$. There is a slight tendency towards grading within the conglomerate beds.

A theory which may explain the origin of these beds, over- and underlain by normal siltstones, was offered by Carey and Ahmad (1961). Thus, a till, deposited in the 'grounded shelf zone' by a wet-base glacier, may develop an unstable submarine slope at its seaward edge. Resulting mud slides cause redeposition of the till at lower levels and interstratification with normal deep sea sediments. Numerous ice-rafted erratics in the Ferntree Mudstone establish that the required glacial conditions prevailed at the time of deposition. Unfortunately, no definitely striated or faceted pebbles were found at Kingston and the bathymetry of the Ferntree Mudstone is uncertain.

Specimen 878 was taken from the Ferntree Mudstone south of Boronia Beach. In a polished and a thin section of this rock, small-scale festoon cross-bedding can be distinguished (Plate 1, Fig. 4). The rock is a poorly-sorted sandstone with fragments of generally low sphericity and high angularity. It consists of 70% matrix containing 30% fragments (including quartz 40%, feldspar possessing the optical properties of bytownite (20%) and 10% muscovite and opaque minerals. The cross-bedding, poor-sorting, low sphericity and high angularity of grains in this rock again suggest deposition under turbulent conditions. Laminations bend over and under the clastic fragments but do not appear to be broken by them.

Although fossils are not abundant in the Ferntree Mudstone, a bed several metres below the conglomerate beds on Flowerpot Point contains *Megadesmus grandis*, *Astartila intrepida* and *Vacunella curvata* (identified by Dr B. Runnegar, University of Queensland, see Runnegar, 1967, fig. 1 and p. 11). *Stenopora crinita* and silicified coniferous wood were identified from the north end of Blackmans Bay. *Stutchburia compressa* and *Astartila intrepida*, present in the Ferntree Mudstone at Kingston, are characteristic Upper Permian fossils.

In the Ferntree Mudstone north of Kingston Beach there are numerous nodules containing pyrite as small cubic crystals (sp. 901). A variety of sulphate minerals have accumulated as a result of the action of water on the sulphide (similar to that suggested by Schlar, 1961). The minerals are listed in Table 1.

The soda alum gives a somewhat similar X-ray diffraction pattern to that of potash alum, but a flame test gives a positive result for sodium. The presence of soda alum is interesting because it is rare as a naturally occurring mineral. Mendosite, which has the same composition as soda alum but is not isometric, does occur in nature (Dana, 1957, p. 764), but has not been indexed in the

TABLE 1

Mineral	Formula	D-Spacings, Angstrom Units					
		Measured			From A.S.T.M. Index		
melanterite	$FeSO_4 \cdot 7H_2O$	4.87	3.76	3.25	4.90	3.78	3.23
potassium aluminium sulphate hydrate (potash alum)	$KAl(SO_4)_2 \cdot 12H_2O$	4.28	5.04	5.45	4.30	3.25	4.05
soda alum	$NaAl(SO_4)_2 \cdot 12H_2O$	4.29	3.24	4.06	not recorded		

A.S.T.M. index. Another sulphate mineral identified in the Kingston area is epsomite, $MgSO_4.7H_2O$, encrusting joint surfaces in a cliff-cave south of Boronia Beach. The crystals are well-formed, orthorhombic fibres.

Triassic System

Although there are few outcrops of Triassic sandstone, a white quartz sand derived from it covers a large area. The thickness of Triassic sediments is at least 85 m. in the Boronia Hill section. Triassic sandstones lie with slight angular discordance on Permian sandstones and siltstones. There is a regional dip of 5° to the south-west. The dip is slightly less than that of the underlying Permian beds (dip 7-8°) but the strike is the same. The base of the Triassic sediments can be traced from the centre of Blackmans Bay Beach north to the Channel Highway, where it is at an altitude of approximately 30 m. It can also be seen on the cliff above Flowerpot Point. By using the measured dip and strike for Triassic rocks on Boronia Hill, the Triassic-Permian contact may be plotted. This coincides with the points at which the actual contact can be seen, e.g., on Roslyn Avenue.

Further study is required to establish whether the Triassic rocks in the Kingston area can be correlated with the Knocklofty Formation or with the Springs Sandstone. Correlation is hampered by lack of outcrop, intrusion of dolerite and faulting. McLeod (1961), called the Triassic rocks at Whitewater Creek the Ross Sandstone of Lower Triassic age. This is following the nomenclature of Jennings (1955) who used this name for the basal 100 m. of the Triassic System.

The basal beds above Flowerpot Point and in the cutting behind Blackmans Bay Beach (spp. 909-911) are a greyish orange, micaceous and graphitic, fine to medium sandstone. They contain white, subangular quartz in a yellow clay matrix. Iron staining produces an irregular banded appearance. Several feet higher in the section the sediment is a coarse to very coarse sand containing fairly well-rounded quartz grains (S/R = 0.7/0.7) in a fine grained matrix. Mica and graphite flakes are not as common as they are in the lower beds. Cross-bedding, indicating a current from the west, is present and there is a small fossil stream bed exposed in the section. This is ½ m. wide by ¼ m. deep and extends at the top into a narrow horizontal band of pebbles. The pebbles are chiefly quartzite and there is slight vertical grading. The sandstone characteristically weathers to rounded outcrops which are red due to iron staining in weathered specimens. The clay matrix is probably removed by leaching processes leaving a white quartz sand which is used commercially.

At the north end of Kingston Beach the basal beds contain mica and needles of tourmaline, and contain a band about 3 cms. thick composed of quartz pebbles up to 4 cms. long in a sand-grade matrix. Higher in the section the sediment is harder, more compact and finer grained. Specimen 918 is composed of 80% quartz in a clay matrix (kaolinite or muscovite), with rare crystals of plagioclase approximately 0.4 mm. in diameter. The quartz has straight, or in come cases undulose extinction. Some grains are composite but have no inclusions. The grains are about 0.4 mm. in diameter and their sphericity to roundness ratio is 0.7-0.9/0.3. There is little variation in grainsize.

Triassic sandstone with an even and close bedding is taken from the quarry on Kingston Road, Bonnet Hill, for use as paving and building stones (spp. 926, 924). This is part of a small 'island' of Triassic sediment surrounded by the Bonnet Hill dolerite, but it is not appreciably metamorphosed by the dolerite. It dips at 10° to the north-west with a strike of 330°. Bedding is from 3 cms. to 45 cms. thick and the outcrop is well jointed. Two main rock types are exposed in the quarry. The lower one is a fine sand which is very pale orange and consists of sub-angular quartz grains in a clay matrix. Overlying it is a medium-grained sand in which bedding is less well developed. Cross-bedding is absent. The relationship of these Triassic sediments to those on Tyndall Road and south of Kingston cannot be determined because the section is broken by the dolerite intrusion.

In all outcrops seen in this area, the current direction, as determined from cross-bedding measurements, appears to have been from the west. The fossil stream bed above Flowerpot Point indicates flow of water from either the west or the east. A westerly current direction agrees with observations elsewhere in Tasmania except at Dover where the current apparently had an easterly source (Hale, 1962). The coarse sandstone sequences, the current bedding and the fossil stream bed are characteristic of deposition in shallow water. It has been suggested (Hale, 1962, p. 230), that the sediments are of fresh water origin due to lack of marine fossils and the presence of terrestrial plants in Triassic sediments in other parts of Tasmania.

IGNEOUS ROCKS

Jurassic Dolerite

Tholeiitic dolerite, of Middle Jurassic age (McDougall, 1962) intruded into Permian and Triassic rocks in the form of sheets and sills.

Intrusion appears to have been at two stratigraphic levels:—Into the Lower to Middle Permian, in particular the Grange Mudstone; and into Triassic sandstone. The trend of the discordant contacts is roughly parallel to that of the major faults. This will be discussed in a later section.

Exposed on the point at Boronia (5187, 7077) are fine-grained dykes (sp. 933) intruded into the coarser dolerite. The thickest dyke is 1.6 m. thick, narrowing to approximately 0.7 m. at its highest outcrop in the cliff. The contact is irregular and stepped, but the general trend is 70°. About 30 m. to the south a series of dykes from 5 cms to 15 cms. wide trend at 80°. The dykes are cut by the strong regional jointing at 310° (see structure section), but another near-vertical set of joints has developed within the dykes and roughly parallel to their margins. These are probably caused by stresses during cooling. The dyke rocks are composed of multiply-twinned laths of labradorite (50%), subhedral pigeonite crystals (45%) and an opaque mineral, probably ilmenite, in a groundmass of mesostasis containing numerous opaque grains, small feldspar laths and rounded pyroxene grains. The texture is ophitic. The composition of this specimen is similar to that of the coarser-grained dolerite in the area.

Tertiary Basalt

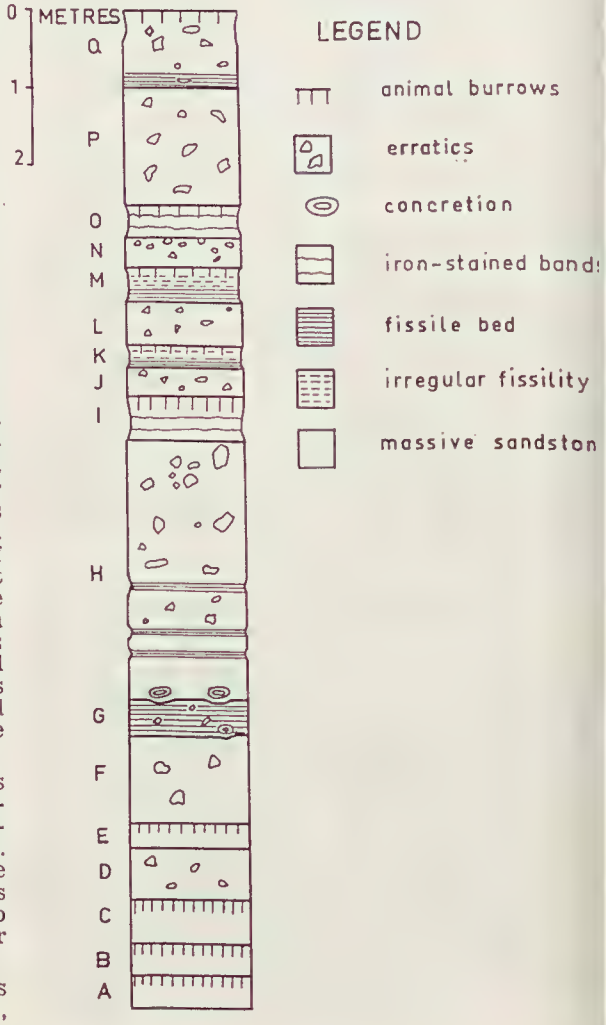
Olivine basalt (spp. 940, 941), which post-dates the Tertiary faulting, covers much of the mapped area. There is little outcrop as most of the basalt is covered by a rich, red-brown soil. There are three main basalt masses:—The Mount Pleasant basalt exposed on Leslie Road, the Browns River Road basalt and the Doctors Hill basalt. From structural evidence it would appear that these three masses are remnants of a single flow. Thus, if approximate contours of the pre-basalt topography are plotted (assuming that the basalt post-dates the faulting), there is a steady fall in altitude from the north-west and flow lines within the basalt are consistent with this direction. Nevertheless, the Mount Pleasant basalt is mineralogically distinct from the other two masses. The Browns River Road and Doctors Hill basalts are oligoclase basalts according to the classification of Edwards (1950). In thin section they are seen to be composed of olivine phenocrysts which have been largely (but often incompletely) altered to iddingsite. The iddingsite is brown with slight pleochroism, high birefringence and high relief. The oligoclase laths are flow-aligned, especially in the Doctors Hill specimen, and rough banding up to 1 cm. wide is visible. Ilmenite is present as small, even-grained granules scattered throughout the section. The texture is intergranular.

The basalt from Leslie Road contains phenocrysts of olivine and colourless augite with some irregular-shaped ilmenite crystals in a groundmass of labradorite, greenish-brown glass and a little quartz. The texture is intersertal to intergranular. There is no marked flow orientation in this specimen. This basalt best fits the Mersey Type according to Edwards' classification, although the glass is greener and more abundant.

Where the southern extremity of the Doctors Hill basalt crosses the Channel Highway (5141, 7067) an interesting contact between the basalt and Lower Permian sediments is exposed in a road cutting. The contact is steeply dipping and a narrow band of red scree material separates the slightly thermally metamorphosed sediment from the weathered basalt. This exposure may be explained by postulating a pre-basaltic valley cut in Lower Permian sediments, down which the basalt flowed.

A specimen of clay taken from a vertical joint in the outcrop at the Howden Road turnoff was shown by differential thermal analysis to be a *nontronite*. It has probably formed from the olivine in the Doctors Hill basalt and has subsequently migrated into joints in the underlying sediment. Allen and Scheid (1946) suggested that weathering under conditions of poor drainage is essential for the formation of nontronite.

FIG. 2



STRUCTURE

The area can be conveniently divided into two structural units separated by the North-West Bay Fault which extends N.N.W. (strike 350°) from the northern end of North-West Bay. The fault is concealed by the Doctors Hill basalt flow but appears to bifurcate where it emerges north of the flow, introducing a narrow wedge of Ferntree Mudstone between the Triassic and Lower Permian sediments. Both blocks are downthrown to the east. A fault which cuts Leslie Road at (5135, 7098) has a similar displacement (400 + m.) to that of the North-West Bay fault. Its southern extremity is hidden by the Mt Pleasant basalt but it is probable that it is an extension of the North-West Bay Fault.

Eastern Structural Unit

In the eastern unit a north trending fault has brought into contact Permian rocks (Ferntree Mudstone) to the west with Jurassic dolerite to the east, i.e., it is downthrown to the east. On Boronia Point the dolerite-Ferntree Mudstone contact is probably an extension of this fault. This conclusion is supported by the medium-grained character of the dolerite and a similar vertical displacement to that near the Kingston Golf Course clubhouse (5175, 7097). The adjacent sediments do, however, seem to be slightly thermally metamorphosed. The strike of the contact at Boronia Point is 332°. The movement is probably Jurassic and associated with the dolerite intrusion, but its trend is parallel to the preferred direction of Tertiary faulting (Banks, 1958a).

Kingston Beach occupies a graben formed by the previously described fault and a north-east trending fault which abuts onto it. A small meridional fault with a throw of probably less than 16 m. brings a coastal strip of Ferntree Mudstone into contact with Triassic sandstone on Bonnet Hill. Minor faulting can be seen along the coast and two small faults are exposed in the cliff section of Ferntree Mudstone north of Kingston Beach (5193, 7094). One strike (37°) is almost vertical with the east side downthrown by about 2 m. Nearby, a fault with a throw of 0.3 m. dips 60° to 287°.

Western Structural Unit

The discordant contacts in the western unit and in the area to the south-west mapped by McDougall (1962) have the same trend as the large Tertiary faults, suggesting a relationship between the Jurassic and Tertiary movements. A fault, roughly parallel to the North-West Bay fault, has been postulated to explain the discontinuity of the Grange Mudstone between the east and the west of the valley at (513, 707). The west side has been downthrown with respect to the east, the reverse of most faults in the area. Probably this is a Jurassic fault associated with the dolerite intrusion. Dip measurements of sediments on Parks Hill indicate that the dolerite body to the north may extend under the Grange Mudstone and dome it slightly. The slight thermal metamorphism of the Grange Mudstone is a result either of the underlying dolerite or a surface extension of the Doctors Hill basalt which has subsequently been eroded away.

Jointing

Where exposure permits, joint directions have been measured to investigate correlation between jointing, faulting and intrusion of dolerite. The results, plotted on a Schmidt equal area net, are shown in Figs. 3, 4 and 5. Measurements were made chiefly along the coastal sections and in road cuttings.

Jointing in Lower Permian Rocks

Fig. 3 shows joint measurement in Lower Parmian rocks exposed in a road cutting at the Channel Highway-Howden Road junction. Two sets of joints are well developed at right angles to the bedding planes. There are two maxima, at 75° (strong) and 165° (diffuse), corresponding to joints striking at 345° and 75° respectively. The strike of the bedding is 30° and that of the nearby North-West Bay Fault is 350°. It is noticeable that one of the joint maxima is close to the strike of the North-West Bay Fault.

De Sitter (1956, pp. 128-130) described similar jointing in lignite beds in which there are two sets of joints approximately at right angles. The main set is parallel to the dominant fault direction, the other set is perpendicular to it. The joints are *shear joints* and are due to the same stress conditions as the normal faults. Thus it seems that jointing in the Lower Permian rock is associated with the development of the North-West Bay Fault which is probably a Tertiary movement.

Jointing in the Dolerite and Upper Permian Rocks

There are several well-developed sets of joints in both the Jurassic dolerite and the Ferntree Mudstone on the coast at Boronia Point (see Figs. 4 and 5). The average values for the strike of the main sets are tabulated below:—

Ferntree Mudstone	55°	310°	15°	80°
Jurassic dolerite ..	60°	310°	15°	(155°)

In addition, the dolerite contains a set of almost horizontal joints (dipping at about 7° to the north) which are interpreted as cooling joints. Joint directions in the sediment adjacent to the dolerite tend to cluster about 55° and 310° but those south along the coast are more variable. The coastal joint directions differ from those measured in the Lower Permian rocks.

Jointing in Triassic Sandstone

Well developed joints in the freestone quarry on Bonnet Hill have been measured and their directions and dips plotted and contoured. There is a direction maximum at 312° with the joints dipping at approximately 60° to the north. There is a weaker maximum at right angles, in which joints dip at approximately 75° to the east.

Jointing in Basalt

A very prominent set of joints is seen in the basalt where the Electrona powerline crosses the Longley Road. These dip at 20-40° south-east with a strike of 10-20°. At right angles to this there is a poorly developed set. The variation in dip and the curvature of these joints suggest that they are a cooling phenomenon and are probably roughly parallel to the original topographic surface over which the basalt flowed.

Jointing in Lower Permian Rocks, Channel Highway.
80 readings

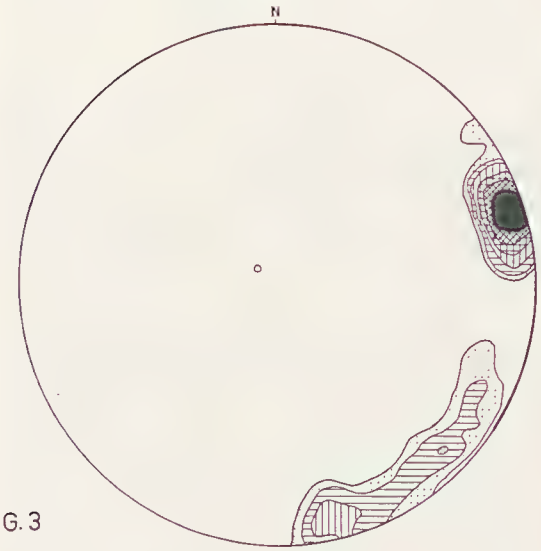


FIG. 3

Jointing in Ferntree Mudstone, coastal outcrop.
50 readings.

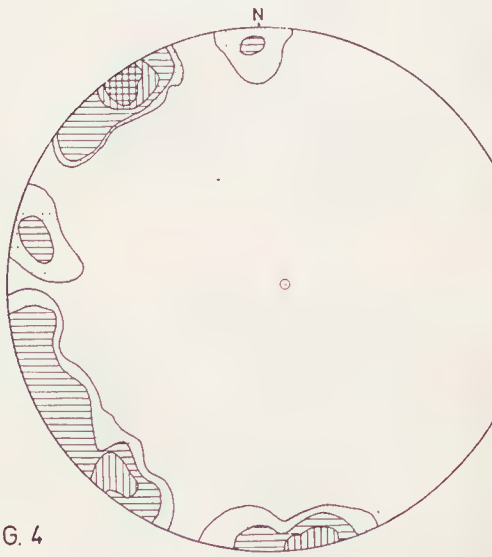


FIG. 4

Jointing in Dolerite, Boronia Point.
55 readings.

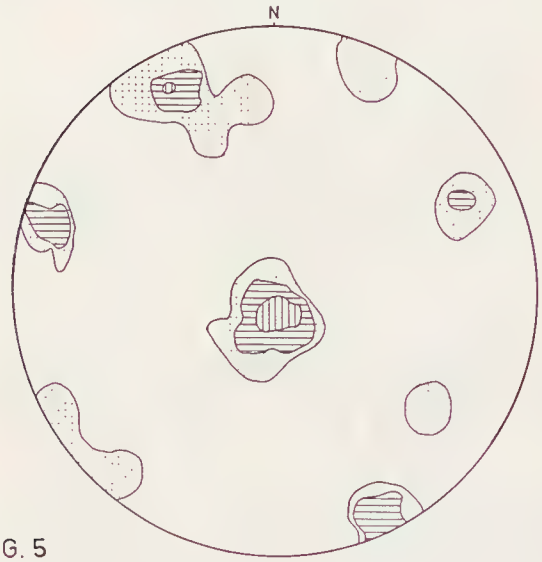


FIG. 5

LEGEND

Percentage

- 2–5
- 5–10
- 10–15
- 15–20
- 20–25
- >25

Pole of bedding

FIG. 3

Summary of Structure

In the Kingston area there is a marked parallelism of Jurassic and Tertiary structures. The trend of these is approximately 330° (N.N.W.), which is also the general strike of the bedding in Permian and Triassic rocks. Jointing can, in some cases, be correlated with the Jurassic and Tertiary movements.

References

ALLEN, V. T., and SCHEID, V. E., 1946.—Nontronite in the Colombia River Region. *Am. Mineral.* 31, 294-312.

A.S.T.M., 1962.—*Index to the X-ray Powder Data File.* American Society for Testing and Materials.

BANKS, M. R., 1958a.—A Comparison of Jurassic and Tertiary trends in Tasmania. pp. 231-264 in *Dolerite Symposium.* Univ. Tasm.

————, 1958b.—Recent additions to knowledge of the Permian System in Tasmania, pp. 151-177 in *Symposium on Gondwanaland. 20th Int. Geol. Cong.*

————, 1962a.—Permian System in *The Geology of Tasmania, J. geol. Soc. Aust.*, 9 (2), pp. 189-216.

————, 1962b.—The Malbina Siltstone and Sandstone. *Pap. roy. Soc. Tasm.*, 96, pp. 19-31.

————, and HALE, G. E. A., 1957.—A type section of the Permian System in the Hobart area. *Pap. roy. Soc. Tasm.*, 91, pp. 41-64.

CAREY, S. W., and AHMAD, N., 1961.—Glacial Marine Sediments in G. O. Rassch (Ed.) *Geology of the Arctic.* Vol. 2, pp. 865-894, *Proc. 1st Int. Symp. Arctic. Geol.*

DANA, E. S., 1957.—*A Textbook of Mineralogy,* John Wiley and Sons, London.

DE SITTER, L. U., 1956.—*Structural Geology,* McGraw-Hill, New York.

EDWARDS, A. B., 1950.—The Petrology of the Cainozoic basaltic rocks of Tasmania. *Pap. roy Soc. Vic.*, 62, pp. 97-120.

FARMER, R. S. J, 1963—Geomorphology of the Coast between Taroona and Blackmans Bay. Unpublished Honours Thesis, Univ. Tas.

GREEN, D. C., 1961.—The Geology of the South Arm-Sandford Area. *Pap. roy. Soc. Tasm.*, 95, pp. 17-34.

HALE, G. E. A., 1962.—Triassic System in *The Geology of Tasmania, J. geol. Soc. Aust.*, 9 (2), pp. 217-232.

JENNINGS, I. B., 1955.—Geology of portion of the Middle Derwent Area. *Pap. roy. Soc. Tasm.*, 89, 169-190.

KRUMBEIN, W. C., and SLOSS, I. L., 1958.—*Stratigraphy and Sedimentation.* W. H. Freeman and Co., San Francisco, California.

LEWIS, A. N., 1946.—*The Geology of the Hobart District,* Mercury Press, Hobart.

LOVEDAY, J., 1955.—Reconnaissance Soil Map of Tasmania, Sheet 82-Hobart. *C.S.I.R.O. Division of Soils, Divisional Report,* 13/55.

MCDOUGALL, I., 1959.—The geology of the Pontville-Dromedary Area, Tasmania. *Pap. roy. Soc. Tasm.*, 93, pp. 59-70.

————, 1962.—Differentiation of the Tasmanian dolerites: Red Hill dolerite-granophyre association. *Geol. Soc. Amer. Bull.*, 73, pp. 279-316.

MACLEOD, W. N., 1961.—Proposed dam site, Whitewater Creek, Kingston. *Tas. Dept. Mines Technical Rep.*, 6, pp. 59-60.

RODGER, T. H., 1957.—The geology of the Sandfly-Oyster Cove Areas, Tasmania. *Pap. roy. Soc. Tasm.*, 91, pp. 109-114.

RUNNEGAR, B., 1967.—Desmodont Bivalves from the Permian of Eastern Australia. *Bur. Miner. Resourc. Bull.*, 96

SCHLAR, C. B., 1961.—Decomposition of pyritized carbonaceous shale to halotrichite and melanterite *Am. Mineral,* 46, pp. 754-756.

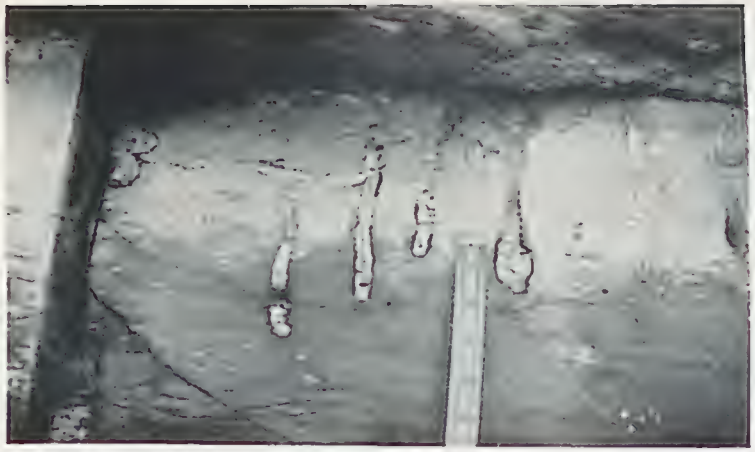
WOOLEY, D. R., 1959.—The geology of New Norfolk-Black Hills district. *Pap, roy. Soc. Tasm.*, 93, pp. 97-109.

APPENDIX

(See Fig. 2)

Beds	Thickness (metres)	Description
A.	0.43	Sediment similar to C.
B.	0.43	Sediment similar to C. A few larger erratics near the top—up to 2″ in diameter, angular, and at different orientations with respect to the bedding planes. Contains numerous burrows which can be seen well in section on the wave-cut platform. Burrows occur in the top 6-9″.
C.	0.56	(specimen 883). Contains very numerous burrows in the top 6″. These are smaller and of finer material than those in bed E to the north.
D.	0.69	(specimen 882). Contains no burrows; erratics are up to 3″ in diameter, S/R = 0.3/0.5. The sediment is hard and white.
E.	0.31	(specimens 874, 881). Contains numerous animal burrows which are about 1½″ in diameter. They extend almost to the base of the bed and are filled with sandy, very poorly sorted material containing quartzite and shale fragments.
F.	1.14	Sediment is similar to H.
G.	0.46	(specimen 880). A fairly soft and fissile bed; lensing from 1′ 6″ to 6″; erratics are a few small quartzite pebbles which are fairly well-rounded.
H.	3.35	A fairly homogeneous sediment containing three narrow (6″) bands which are more fissile although of similar rock type; erratics are much larger and more frequent at the top; their shapes are very variable; in the lower 2′ is a band of large concretions.
I.	0.56	(specimen 875). Contains very numerous sandy animal burrows which are thick and almost vertical; the bed varied in thickness along the strike; it is slightly graded and has iron-rich bands near the base; fissile; erratics mainly of quartzite.
J.	0.36	A turbidite bed containing numerous erratics; sphericity is very variable, R = 0.3; very poorly sorted, erratics are granite, quartzite, shale, sandstone and fine conglomerate.
K.	0.31	(specimen 878). Animal burrows are not numerous; an irregular fissility; contains numerous small quartzite erratics (½ cm. in diameter) which are fairly well rounded (S/R + 0.7/0.5); there are also larger, angular erratics up to 3″ in diameter. See plate and description.

Beds	Thickness (metres)	Description
L.	0.56	(specimen 876). Similar to J but with smaller and fewer erratics; contains small flakes of white mica and a ferro-magnesian mineral.
M.	0.43	(specimen 885). Contains animal burrows; a dark, very fine sandstone with long tapered wafers of a coarser sediment similar to the bed below, suggesting currents which broke off part of the underlying sediment; the fragments are roughly horizontal.
N.	0.38	(specimen 879). Dark grey, with white, irregular streaks; at the top are numerous angular erratics up to 2″ across; contains several sandy cylinders with a circular cross-section; they extend up to 2″ into the bed from the upper surface and may be animal burrows.
O.	0.43	Fairly regularly laminated with sparse burrows and narrow iron-rich bands.
P.	1.52	as M.
Q.	1.02	Sediment similar to M; burrows in the top 1″; erratics are bigger and more numerous towards the top.



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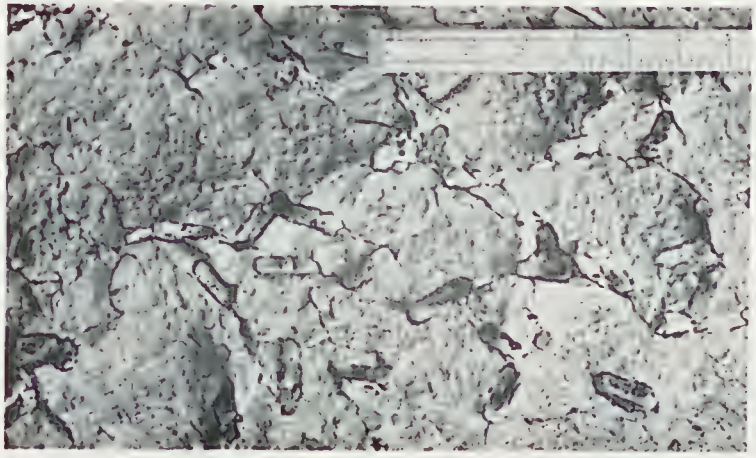

2

FIG. 1.—Animal burrows in Ferntree Mudstone, Kingston. Vertical section.
FIG. 2.—Animal burrows in Ferntree Mudstone, Kingston. Horizontal section.

3

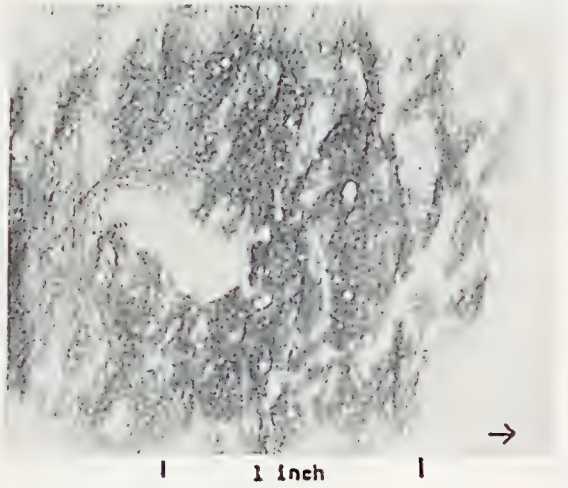

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FIG. 3.—Concretionary structure in Ferntree Mudstone, Kingston.
FIG. 4.—Specimen of Ferntree Mudstone showing rock fragments and small-scale cross-bedding. (Arrow indicates direction of underlying bed)

DISPERSAL OF ACTIVITIES—THE EAST TASMANIAN ABORIGINAL SITES

By

Harry Lourandos
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(With two diagrams)

ABSTRACT

The archaeological evidence both from excavated sites and field survey suggests a significant division in the prehistoric economic organisation of the Tasmanian Aborigines of the East and West/North West habitats of the island. A nomadic organisation is interpreted for the Eastern sites, and a semi-sedentary or seasonally-sedentary organisation for the West and North-West coastal sites.

INTRODUCTION

Here is a scheme based on field survey and excavation for organising and interpreting the archaeological sites of Eastern Tasmania. Three types of site are distinguished and shown to be related spatially and in function. These are shell middens, open inland camps, and the quarries. As a group they are compared with the dominant sites in the West and North-West and shown to be significantly different. These differences are interpreted as reflecting the peculiarities of the separate habitats of East and West (including North-West) Tasmania.

These differences in East and West sites were first noticed by myself during field surveys carried out in 1967 and demonstrated by excavation of two chosen sites (December 1967-February 1968).

Eastern Tasmania I distinguish as the eastern half of the island corresponding to the sclerophyll forest area (shown in diag. 1), with the exception of the coastal heath strip along the North-East coast and in the North-East corner, with an extension on to the lakes area of the Central Plateau demarked as mountain moorland. The West refers to the basically narrow coastal strip predominantly of sedgeland checked by rain forest with large stretches of sedgeland in the South-West. Together with it I include the North-West coast as an extension of the narrow coastal strip probably originally of predominant coastal heath checked by rain forest (shown as 'cleared land' in diag. 1). Most of the East is cut off from the West by large tracts of rain forest, the two habitats meeting coastally in the mid-north and in the extreme south.

THE MIDDENS

Two major types of midden distinguishable in shell-composition and habitat predominate along the East and South-East coasts, the bay estuarine and the open coastal rocky-platform types. Each midden appears to closely reflect the structure of the economically obtainable[1] shell population in the immediately related habitat, with few other extraneous features associated. From Great Oyster Bay south the coastline is broken and indented in series of protected bays, and here and in the estuaries the bay-estuarine type predominates. From field surveys it appears to directly correspond to the distribution of the living and historically recorded shell populations. The two shell species that compose the bulk of these middens are the Tasmanian mud oyster (*Ostrea angasi* Sowerby, 1871) and mussel (*Mytilus planulatus* Lamarck, 1819) and they occur together in differing ratios or independently according to the structure of the associated shell populations. North of Great Oyster Bay as far as Eddystone Point the dominant midden is of the second type directly associated with shell populations sharing the exposed rock-platform habitats that make up most of this coastline. The dominant species in association here are the *Subninella undulata* Solander, 1786 and a species of Abalone (*Notohaliotis ruber* Leach, 1814). Location and morphology (as well as shell composition) of the middens along these coasts is governed by that of the obtainable shell populations immediately associated. The middens have been accumulated directly on the coastline with few exceptions[2] within a few feet of the mollusc habitats.

The total compositions of all midden types in the area appear to be predominantly of shell with low proportions of, terrestrial and marine faunal remains, definable stone implements, flaking floors, or structural features. Large sample excavations on one midden in the Little Swanport estuary[3] have verified this observation. The ratio of the midden's contents heavily reflect that of the oyster/mussel population immediately associated[4]. All other traits are very poorly represented. Few terrestrial and coastal-marine faunal remains are present. The frequency of stone artifacts is very low and all appear imported. No flaking floors were found and the existence of any primary flakes is dubious. Apart from local igneous stone lumps present the use of stone artifacts seems minimal, and negligible numbers of flakes with secondary retouch are present. Except for one possible post-hole and a matrix of ashy hearth lenses no other non-shell structure was apparent. The interpretation is of a specialised oyster-fishing dump with little other activity reflected archaeologically.

Contemporary ethnographic descriptions of open coastal shell middens in the South-East (Hiatt,

1967, pp. 127-128) show a strict exploitation of the immediate coastal habitat, the diet at these sites repeatedly consisting of shell-fish, sea and land vegetable (immediately procurable), crustacea, and fresh water. The open coastal factor of crustacea (usually crayfish) which share this habitat could be expected to be found archaeologically on open coastal middens and perhaps proportionally. In the estuarine Little Swanport midden they were present but in low numbers. For these reasons the ecological interpretation of the specialised shell dump can be extended to all such middens, estuarine or coastal, in this area. By plotting the volume, density, and extent of these midden concentrations (diag. 1) the importance of certain coastal areas as foci[5] of economic exploitation and activity can be noticed. This applies to the entire Tasmanian coastline.

It appears that the East coast was occupied primarily for marine exploitation. Old dates from South-East coast middens fall within the range of c. 6,000-8,700 B.P. (Reber, 1965, pp. 264-67; 1967, pp. 435-436) corresponding to the approximate age of the present coastline and therefore of the shell beds.

INLAND CAMPS

The East is a blanket of artifacts and artifact assemblages stretching from the coast to moorland over 3,000 feet on the Central Plateau. Implement scatters are detected in ploughed fields, along the eroded perimeters of inland lakes and marshes, and are stratified in sedimentary deposits alongside water-courses. The entire Eastern habitat appears to have been under Aboriginal occupation. Ethnographic verification exists in support of the archaeological evidence (Hiatt, 1968, pp. 190-205). Two major types of archaeological sites have been recognised, stratified deposits in rock shelters and lunettes (fossil inland dunes). Rock shelters and overhangs are commonest in the sandstone outcrops which occur throughout the East, and are prominent in weathered faces along old water courses[6]. The lunette sites, their geomorphological and their temporal significance, have been discussed by Jones[7].

Crown Lagoon[8], a lunette site, was excavated by myself this year. It is situated approximately sixteen air-miles west of the excavated Little Swanport midden on the same river system and 2,000 feet higher up. The cultural deposit lies beneath the modern dune surface in an ancient soil profile[9] within the top two and a half feet of the lunette. Its contents provided a stone assemblage of wide range including flaking floors of cores, finished implements (basically similar to those from Little Swanport), with large numbers of flakes showing secondary retouch and a bulk of primary flakes and chips. With these were sandstone pieces showing use-markings and grooves (interpreted as abrasive tools), grinding stones and pounders, and large stone lumps. All stone material must have been carried onto the dune and included a large range of parent materials suggesting importation from a sizeable range of quarry-sites. The stone was associated throughout with poorly preserved bone material, some identifiable as marsupial, and with a series of small hearth pits dug in sand. The interpretation is of an 'inland camp' plausibly associated with the lake or marsh in front and showing the manufacture, use and resharpening[10] of stone implements on the site, in association with faunal evidence, the hearths, and the grinding equipment inferring the eating of vegetables[11]. This interpretation has been extended to those inland sites, both stratified, eroded and surface, which show a similar assemblage of stone types. Such are the lunettes in the Midlands (as at Grimes Lagoon and Lake Dulverton) and the erosion scatters round the lakes of the Central Plateau detected as far west as Lake Augusta.

THE QUARRIES

The most common stone material used in the East for manufacturing flaked stone tools was of fine-grained siliceous rocks predominantly from Jurassic and Tertiary chert-hornfels (metamorphosed mudstones and sediments). The area where this material occurs is shown in diag. 2 and appears to correspond broadly to the extent of the sclerophyll East. Here the material outcrops ubiquitously and abundantly, and a distribution of the quarries could be expected to coincide. The plotting of certain known quarries[12] reflects this. The quarries' composition is predominantly of used cores and primary waste flakes with few finished implements. This infers that the quarry site was used for the initial manufacturing of the stone implements which were then carried off the site presumably for use elsewhere. Quarries often occur fortuitously in close proximity to occupation sites as in the Little Swanport estuary, Oyster Cove (D'Entrecasteaux Channel), Long Point and Piccaninny Point.

INTERPRETATION

The three types of site described show basic dissimilarities in their function, in stone implement manufacture and use, and in the exploitation of the immediate habitat. Coastal shell middens (including estuarine) reflect a predominant coastal (or estuarine) exploitation with terrestrial features very poorly represented. Inland camps produce in proportion a totally different assemblage of stone types [13], and the quarries reflect primary stone implement manufacture. The three sites are highly specialised, limited in function and interdependent, and this is interpreted as reflecting the cultural interdependence of two distinct habitats, the coast and the sclerophyll hinterland.

THE WEST AND NORTH-WEST

Archaeological sites along the West coast are predominantly coastal with few sites reported inland (map, Bryden & Ellis, 1965, p. 38). These shell middens are more complex than those in the East with extra traits associated. One major characteristic is the varying degree to which they reflect the exploitation of both coast and hinterland[14]. West Point can be seen as a stabilised base camp at which all the activities represented in the three Eastern sites (except initial rock quarrying) are centralized. These include flaking floors showing primary and secondary implement manufacture and use, and large proportions of grinding and pounding stones (Jones, 1966, p. 6). Added characteristics are well-constructed stone hearths and a cluster of pit depressions conforming to ethnographic West coast

examples of substantial huts and hut clusters (Robinson, March 26, 1830, June 2, 1830, June 6, 1830). These traits are found on other middens down the West coast. The West Point midden accumulated rapidly in hundreds not thousands of years (as in the East and the North-West sites)[25]. From Jones' evidence (Jones, 1966, p. 7; 1967, p. 363). the interpretation here is of high density concentration at the site for significant time periods dependent on the midden's association with the seasonal breeding and moulting of nearby seal colonies. South of West Point equivalent midden volume is found with seal bones associated (diag. 1) detected south to Sloop Point[18] and ethnographically to Cox's Bight (Robinson, Feb. 10, 1830) and the South-West (Robinson, July 15, Dec. 15, 1831). The peculiarities of West Point, its proximity to faunally productive coastal heath[17] (reflected in the high propositions of terrestrial faunal evidence, Jones, 1966, p. 7) and its rapid accumulation might not apply to all West coast middens, most of which have hinterlands of inferior sedgeland[13]. The North-West sites (three excavated by Jones, 1966, pp. 2-6) reflect certain major West coast features; over time[19] an increasing orientation towards both coastal and terrestrial exploitation, and an important dependence on seal. Their premium[20] value lies in their location and their protection-value as caves and shelters. The latter could explain certain specialised features such as the selection in seal carcass evidence present (Jones, 1967, p. 362) and their association with open shell midden dumps nearby.

CONCLUSIONS

This Western group of sites does not conform to the definition of the shell dumps as used for the sites in the East. Their eclectic compositions indicate exploitation of dual habitats, and their coastal location infers a premium value dependent on the superiority of the coastal habitat for exploitation. The key here would be the seal factor, undetected in the East, which would provide the imbalance between coast and hinterland habitats. From midden evidence comparison between East and West coastal habitats indicates the overall greater attraction of the West. Comparison between terrestrial zones shows the largest range of faunal species and numbers in the sclerophyll[21], the coastal heath as an area rich in mammals and birds[22], and the sedgeland as a poor faunal habitat[23]. The content and location of the excavated sites and the field evidence, within limits, appear to reflect these differences (though sites associated with sedgeland are still to be tested). A broad interpretation suggests the interplay between two balanced habitats in the East, the coast and the sclerophyll forest, and between a dominant coast with productive hinterland in the North-West, and inferior hinterland for a significant area of the West coast. The archaeological evidence suggests that Aboriginal economic organisation in the East fits a nomadic non-sedentary pattern incorporating a number of dispersed limited-activity sites; in the West a semi-sedentary or seasonally sedentary organisation with coastal bases[24]. In support there is ethnographic evidence of house-type differences in size, durability, and numerical concentration between the two areas which need not necessarily only reflect climatic differences (Hiatt, 1968, pp. 201-202).

Hiatt provides much evidence for extensive and continual occupation of all major habitats with the exception of the rain forest, and for the concurrent exploitation of both habitats, coast and inland, in both regions East and West (Hiatt, 1968, pp. 190-205). This satisfies the conclusions based on the archaeological evidence. Her data is ethnographic and she deals with a time period during which the Aboriginal occupation pattern had already been severely disrupted by European settlement and enterprise and was continuing to be broken down. The archaeological evidence is almost wholly pre-contact and pre-historic. From her data she concludes that she can detect no marked differences between the economies of the East and the West (1968, p. 218). The archeological evidence allows the suggestion of a definite division in the economic organisation employed in the two areas. Also Hiatt fails to distinguish between the exploitable potential of the differing terrestrial habitats and its significance in their relationship to the coastal habitats.

CRITICISM AND COMMENTS

In selecting data for the scheme put forward above certain restrictions on the material were necessary. In the West only the more conspicuous coastal sites were considered although this itself is telling. In both areas generalisations were made from only six excavated sites but evidence also included that of extensive field surveys. Numerical analysis is now needed to describe many of the conclusions reached, such as the differing ratios of contents between East and West/North-West sites. The factor of time and its effect has been played down to heighten important spatial and functional relationships. Contemporaneity between Eastern sites (whether completely accurate or not) is assumed as no cultural differences over time detected in the excavated sites seem to affect it. Omission is made of the anthropogenic nature of the vegetation and its effects (Jackson, 1965, pp. 30-35; 1968, pp. 50-55; Jones, 1968 (unpublished), sec. c). So too are the cultural changes over time detected at Rocky Cape (Jones, 1966, pp. 2-6, 9) and identified at Little Swanport during its excavation. These are the existence of evidence for fishing and worked bone tools in the basal layers of the sites. This now appears as a Tasmania-wide phenomenon. If it holds true for all the East it would indicate a drop in the premium value of Eastern coastal sites over time, as fishing does not appear to have been replaced by any equivalent food source. And for the whole island it would place a limit on the maximum size of subsequent Aboriginal population.

NOTE ON THE NORTH-EAST

The distinction has already been made between the sclerophyll East and the North-East coast and North-East corner which is a strip of coastal heath behind extensive dunes. Middens at Eddystone Point and further north at Cobler Rocks and Cape Naturaliste have features which tend to associate them with the North-Western sites and perhaps West coast sites in similar vegetation belts.

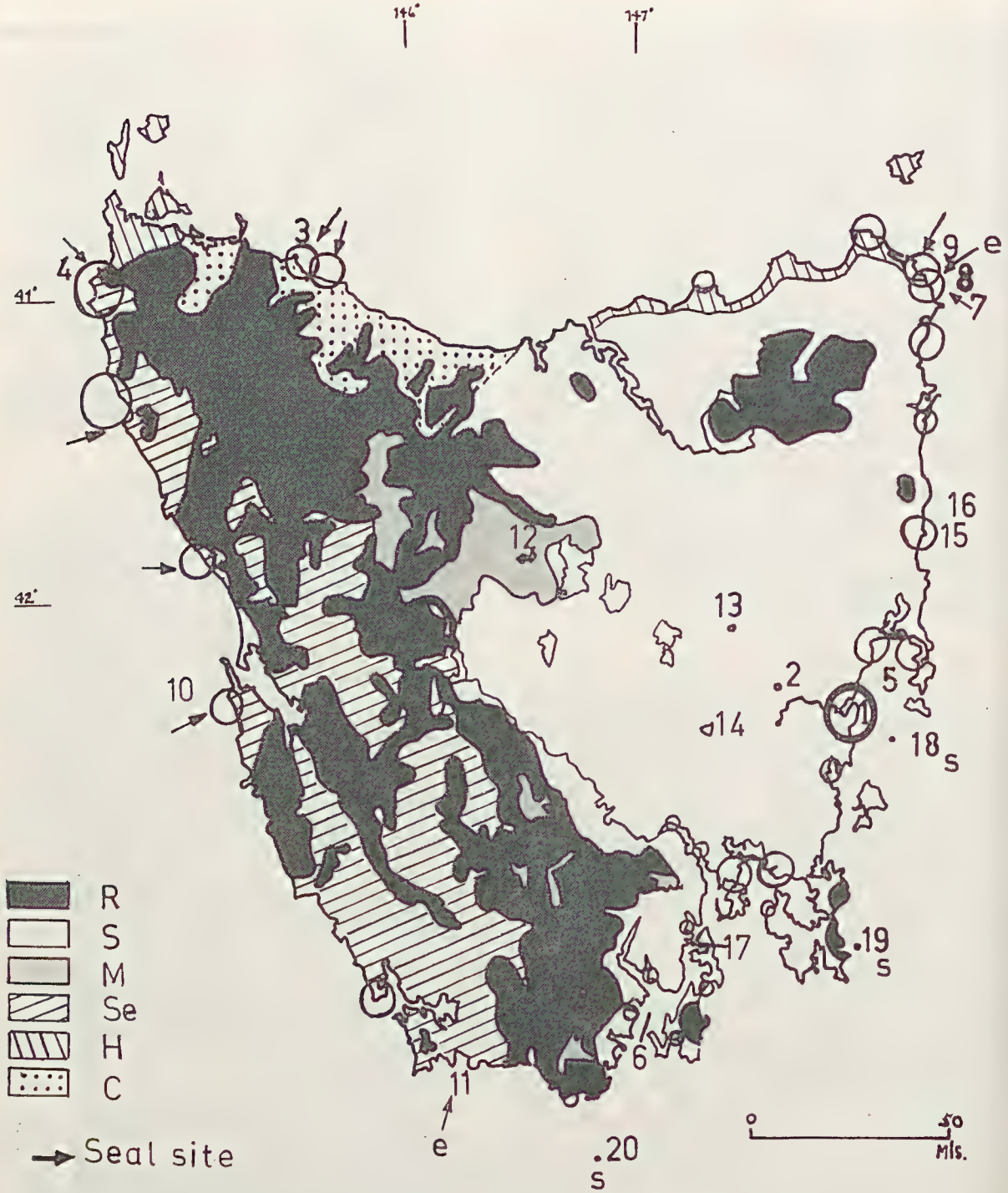

DIAGRAM 1.

Major Vegetation Zones—R, Rain Forest; S, Sclerophyll Forest; M, Moorland; Se, Sedgeland; H, Coastal Heath; C, Cleared Land.
e = ethnographic seal sighting.
s = present day seal colonies.
Sites mentioned in the text—(1) Little Swanport; (2) Crown Lagoon; (3) Rocky Cape; (4) West Point; (5) Great Oyster Bay; (6) D'Entrecasteaux Channel; (7) Eddystone Point; (8) Cobler Rocks; (9) Cape Naturaliste; (10) Sloop Point; (11) Cox's Bight; (12) Lake Augusta; (13) Grime's Lagoon; (14) Lake Dulverton; (15) Long Point; (16) Piccaninny Point; (17) Oyster Cove; (18) Iles Des Phoques; (19) Hippolyte Rocks; (20) Pedra Branca.
O—Circles denote shell midden concentrations and their comparative size.

DIAGRAM 2.—Aboriginal Quarry Sites and Their Likely Distribution. Quarries are indicated by a triangle and plotted against the major outcrop area of chert-hornfels (shaded); this is the most commonly used material for flaked tools in Eastern Tasmania.

Associated with these are significant quantities of marsupial and seal bone in deposits visibly up to five feet thick. This evidence corresponds to a note by Kelly (1920, p. 174) in January 1816 of a seal colony at George's Rocks which lie immediately off the coast between Eddystone Point and Cobler Rocks. Large numbers of Aborigines are associated with the seals and with kangaroo in this description, but as Hiatt warns (Hiatt, 1968, pp. 199, 201) this incident is one provoked by European intervention. Excavation is needed to determine whether this North-East corner corresponds to the later Rocky Cape or West Point model.

Diagram 1 reveals a pattern of Aboriginal sealing with a West/North-West distribution from Cox's Bight to Eddystone Point. This is more extensive than the present distribution centered in Bass Strait with fringe colonies off the main of South-East Tasmania at Isle Des Phoques, Hippolyte Rocks and Pedra Branca[25]. Evidence for Aboriginal association with South-East sealing colonies has yet to be detected archaeologically.

NOTES

(1) This would be determined both by biological and cultural factors involving shell-fishing and its organisation.

(2) One such exception is a rock-shelter on the Tasman Peninsula two to three miles inland between Roaring Beach and Satwater River and a few hundred feet above sea level where up to eight species of coastal shell were recognised.

(3) The excavation material is currently under process of analysis. (The large volume of shell in this estuary and its middens were reported by Taylor, A. J., in 1891.)

(4) These oyster beds were commercially extinguished by 1882. Report to Fisheries Royal Commission of Tasmania, 1883, p. 83.) Up till then the centre of the Tasmanian Oyster Industry had been Great Oyster Bay.

(5) the definition of focus (foci) here is a comparative convergence or concentration of activity at one site or one locality.

(6) Jones, R., 1965, p. 198; Fig. I, p. 4.

(7) 1968, 'Geographical Background to the Arrival of Man in Australia and Tasmania'. Sec. c. 'The Arrival of Man in Tasmania'.

(8) The excavation material is currently in the process of analysis. The site has been referred to before (Jones, 1967, p. 362).

(9) This has been verified by A. Goede, Department of Geography, University of Tasmania.

(10) A characteristic flake with a blunted retouched edge interpreted as a rejuvenation flake was common throughout the site.

(11) The association of the grinding stones with the pounders was archaeologically verified during excavations at Rocky Cape in 1967 (Jones, R., and Lourandos, H., unpublished). Its use is deduced from Australian analogies.

(12) Such quarries as those at St Peter's Pass, Bothwell and Oyster Cove (Channel).

(13) This does not infer a different stone typology.

(14) Differences over time have been neglected here. The early half of the Rocky Cape sequence with a heavy reliance on coastal exploitation and its later change has been interpreted as adaptation to a modified habitat (Jones, 1966, pp. 8-9).

(15) Jones gives a basal date of 1,850 $\pm$ 80 B.P. and a top date of 1,330 $\pm$ 80 B.P. for West Point (Jones, 1967, p. 363). Basal date for Rocky Cape South is between 7,500 and 8,000 B.P. (Jones, 1967, p. 362).

(16) Via personal communication from Mr P. Sims.

(17) Guiler, 1965, p. 37.

(18) *ibid.*

(19) See footnote (14) above.

(20) 'Premium' is a term borrowed from animal ecology and here it is modified to mean a scale of competition between sites in their selection by a human culture.

(21) op-cit footnote (17).

(22) op-cit footnote (18).

(23) op-cit footnote (18).

(24) These arguments have often been suggested but without verification. See Hiatt (1968, p. 202) and her comments on the issue.

(25) Via personal communications with Dr J. L. Davies, Department of Geography, University of Tasmania.

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REFERENCES

AMBROSE, W. R., 1967.—Archaeology and Shell Middens. *Archaeology and Physical Anthropology in Oceania*, Vol. II, No. 3.

BRYDEN, W., and ELLIS, W. F., 1965.—Aboriginal population. In *Atlas of Tasmania*, edited by Davies, J. L.

DAVIES, J. L., no date.—The Whales and Seals of Tasmania, Tasmanian Museum and Art Gallery, Hobart.

GUILER, E. R., 1965.—Animals. *Atlas of Tasmania*, edited by Davies, J. L., Lands and Surveys Department, Hobart.

HIATT, BETTY, 1967, 1968.—The Food Quest and the Economy of the Tasmanian Aborigines (in two parts). *Oceania*, Vol. 38, No. 2; Vol. 38, No. 3.

JACKSON, W. D., 1965.—Vegetation. Atlas of Tasmania, Editor, Davies, J. L.

———, 1968.—Fire and the Tasmanian Flora. *Tasmanian Year Book No.* 2. Commonwealth Bureau of Census and Statistics Tasmanian Office, Hobart.

JONES, RHYS, 1965.—Archaeological Reconnaissance in Tasmania, Summer 1963-4. *Oceania* 35.

———, 1966.—A Speculative Archaeological Sequence for North-West Tasmania. *Rec. Q. Vict. Mus., Launceston*, No. 25.

———, 1967.—Middens and Man in Tasmania. *Australian Natural History*, Vol. 18.

———, 1968.—Geographical Background to the Arrival of Man in Australia and Tasmania. *Archaeology and Phys. Anthropology in Oceania* (to be printed in the October issue).

KELLY, JAMES, 1921.—First Discovery of Port Davey and Macquarie Harbour. *Pap. and Proc. Roy. Soc. of Tasm.* for the year 1920.

KEMP, THERESE BELLEAU, 1963.—The Prehistory of the Tasmanian Aborigines. *Australian Natural History*, Vol. 34, No. 8, Dec. 15.

LOURANDOS, HARRY, 1968.—A Description of the Aboriginal Archaeological Sites in Tasmania, Australian Institute of Aboriginal Studies (to be printed).

———, 1969.—The Study of the Tasmanian Aborigine. *Tasmanian Year Book*, No. 3. Commonwealth Bureau of Census and Statistics Tasmanian Office, Hobart (to be printed).

REBER, GROTE, 1965.—Aboriginal Carbon Dates from Tasmania. *Mankind*, Vol. 6, No. 6.

——— 1967.—New Aboriginal Carbon Dates from Tasmania. *Mankind*, Vol. 6, No. 9.

ROBINSON, GEORGE AUGUSTUS, 1829-1834, compiled in 1966.—Friendly Mission: The Tasmanian Journals of and Papers of George Augustus Robinson, 1829-1834. *Tasm. Hist. Research Assoc. Hobart*, edited by Plomley, N. J. B.

SUTHERLAND, F. L., 1965.—An Analysis of the Rock Types and their Distribution in the Stone Implements of the Tasmanian Aborigine (A.N.Z.A.A.S., Hobart) (unpublished).

TAYLOR, A. J., 1892.—Notes on the Shell Mounds at Seaford, Little Swanport. *Pap. and Proc. Roy. Soc. Tasm.* for 1891.

NOTES ON SOME OF THE TASMANIAN ABORIGINES, AND ON PORTRAITS OF THEM

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ABSTRACT

Notes are given on the parentage and histories of Fanny Cochrane and Mathinna, the first a half-caste Tasmanian and the second a full-blood.

The busts of the Tasmanian aborigines attributed to P.-M.-A.-Dumoutier are all, or nearly all, based on originals by other hands.

Some sculptures by Benjamin Law are listed.

Some new information about Thomas Bock's portraits of the Tasmanian aborigines is considered.

FANNY COCHRANE

Although said to have been a Tasmanian full-blood, there is little doubt that Fanny Cochrane was a halfcaste. James Barnard's paper (1890) describing her as a full-blood was probably written with a view to ensure her a pension: Ling Roth (1898) could find no evidence that she was a full-blood.

Clearly, the question would be settled if her parentage could be determined exactly. Although this cannot be done beyond all doubt, the evidence available points to her having been a halfcaste. A large part of her story can be determined from G. A. Robinson's papers and from the records relating to the Flinders Island aboriginal settlement in the Colonial Secretary's archives at Hobart. It is of some importance to note that in the early records she is referred to as a halfcaste.

There is no doubt that Fanny Cochrane's mother was a Tasmanian full-blood. She was called Sarah and Tibb (Tib) by the whites, the name Tibb occurring in the early Robinson records, and Sarah in the Flinders Island and other records. Robinson gives her native name as PLOO.RER.NEL.LE when first he mentions her, but later refers to her by the name of TARE.NOO.TAIR.RER. There are various spellings of the latter—

TANG.ER.NU.TER.RER to cry (Charles Robinson, ? 1836)
TANGANOOTERA (Sarah) (Ernest Westlake, 1910)
TING.NER.TER.RER
TING.NOO.TER.RER
TING.NOO.TER.RUN.NE
TING.ER.NO.TARE.HER
JACKANOOTHARA weeping very much (Robert Clark, 1845).

Tibb is first heard of in 1830 when G. A. Robinson records in his journal that she was one of two native women living on Woody Island with George Robinson, a sealer. Thereafter she is mentioned from time to time in his journals, and particulars of her earlier history are given in his report on the sealers (June 1831). There are also a number of references to her in census lists, vocabularies and so on; and although the untangling of all these sources presents some ambiguities and confusion, a fairly reliable picture can be built up.

Tibb was kidnapped when a child by James Parish and was taken to the islands. Parish is said to have sold her to John Smith, a sealer, for four sealskins; and Smith later sold her to George Robinson, a sealer who lived on Woody Island. It was there that G. A. Robinson first met Tibb, when he visited the island on 10 November 1830. Robinson the sealer then had two native women living with him, Tibb (PLOO.RER.NEL.LE) and Maria TOO.GER.NUP.PER.TOO.TEN.NER); and there was also a little halfcaste boy, of whom Tibb was the mother and Robinson the father. Tibb had probably been living with Robinson since about 1828, when he came to Woody Island from King Island; and before that with John Smith.

At the time of his visit to Woody Island, G. A. Robinson removed Maria and left Tibb with the sealer, who was an old man; but early in December 1830 he sent James Parish to the islands to obtain native women who were living with the sealers, to bring them to the aboriginal settlement; at this time Parish took Tibb from George Robinson. In May 1831 Tibb left the settlement to join the natives with G. A. Robinson, and she remained with him until the end of the Big River expedition, probably being sent back to Flinders when the Big River natives were shipped there from Hobart on 17 January 1832. She seems to have remained at the aboriginal settlement thereafter, removing with the others in 1847 to Oyster Cove. She died on 3 October 1858.

Tibb's tribe was the PIN.TER.RAIR.ER of Cape Portland (Mussel Roe): in one reference she is said to have been a native of Ben Lomond, but this is apparently a mistake. Her age is given variously as 25 (1831), 36 (1836) and 35 (1837).

M. C. Friend (1847) says that Sarah had four halfcaste children by the sealer with whom she lived, and since being on Flinders Island three children by an aboriginal, of whom two were living; but this may not be exactly correct. Four of the children attributed to her have been identified—

1. *Mary Ann* (see below).
2. Son (name unknown).

Father George Robinson, a sealer; born before November 1830 ('little boy, fine child'). There is

hardly any record of this boy: he is not mentioned as having been removed from Woody Island by Parish at the same time as Tibb, but a list of the natives at the aboriginal settlement in March 1832 shows—'Tibb with child by Row' (the father's name is not clear, and may be an abbreviation for Robinson). The boy was evidently old enough to get along without his mother, because Tibb was with G. A. Robinson on his expeditions from May 1831 until January 1832. The death, from influenza, in March 1839, of 'Sarah's boy' seems to refer to this child.

3. *Fanny Cochrane* (see below).
4. *Adam.*

The 'male child' born 7 June 1838; father Eugene (= NIC.ER.ME.NIC), Tasmanian full-blood; died 28 October 1857, of disease of the lungs and liver, his age being given as twenty. A record dated 13 October 1846 (CSO 11/27) names Adam as half-brother to Mary Ann, and gives his age as about seven or eight.

Mary Ann

Mary Ann, halfcaste wife of the Tasmanian full-blood Walter George Arthur, is generally considered to have been a half-sister of Fanny Cochrane. The relationship has its basis in one of Robinson's lists of the natives at Flinders Island in which he states that Mary Ann was the 'daughter of Sarah by a sealer' and that she had 'lived in service on the Main'; and in a statement which Mary Ann made at an enquiry into affairs at the Flinders Island aboriginal settlement in October 1846 (CSO 11/27) that—'I am half sister to Fanny Cochrane we have the same mother'. These records appear to be reinforced by what she told James Bonwick, viz., that her mother was the aboriginal Sarah and her father the sealer Cottrel Cochrane; and it is implied that this same Cochrane was the father of Fanny Cochrane. However, if Cochrane had been the father of both girls, Mary Ann and Fanny would have been full sisters if they had had the same mother. There is no evidence for the former; and there is even doubt whether the girls were blood relations at all.

No records have been seen which point clearly to Mary Ann's parentage, but it is worthwhile to examine the information available because it is relevant to the problem of Fanny Cochrane's parentage. Bonwick (1870, p. 282) states that Sarah, mother of Mary Ann, had been 'stolen from her forest home by one of the early sealers of the Straits, whose name for Cottrel Cochrane'. First as to Cottrel Cochrane: no sealer of this name is known, though such negative evidence is not of much consequence because records relating to the sealers are quite inadequate, especially before 1830. Next as to Sarah: for her to have been the mother of Mary Ann, her age would have had to be 36 (1836) or 35 (1837) rather than 25 (1831)—Mary Ann's age is given as 15 (1836) and 18 (1837); she married Walter George Arthur on 16 March 1938. On this basis, Mary Ann was born in the period 1819-1821. At that period, it is likely that Sarah (Tibb) was living with the sealer John Smith, who had in his entourage another native woman PLEEN.PER.REN.NER, also named Mother Brown (sometimes Nancy Brown). James Brown, with whom Mother Brown had lived originally, was drowned when James Parish lost his boat off Bird Island (Hunter Group) in May 1818; two of Mother Brown's children were also drowned at the time. Afterwards, Mother Brown lived with Parish for a time, and he then disposed of her to John Smith.

There are a few records relating to Mother Brown: she was living with John Smith in March 1831, and on 1 April or a day or so earlier he brought her to the aboriginal settlement, with her daughter (this daughter was by Brown, not Smith, but she had had children by both men); she was returned to John Smith a couple of months later; she was reported to be living with Smith on Flinders Island in July 1934; she was living with the sealers at Gun Carriage (among whom was John Smith) in January 1936. Of her children we only know that Mary Ann Brown (presumed daughter) aged nine, was living in Launceston in 1827; that in 1831 one of her daughters, aged thirteen, was living with her at the Flinders settlement, and another in Launceston, the father of both girls being Brown. The records relating to Sarah (Tibb) have already been summarised: there is no mention of a daughter Mary Ann; there is no mention of any children except the little boy whose father was the sealer Robinson; if Smith had been the father of any of her children born before 1831, it is not recorded. Unfortunately, Many Ann is not given a surname in the Flinders Island records.

The impression gained from this confusion is that Mary Ann was a daughter of James Brown and Mother Brown. The main argument against this conclusion is G. A. Robinson's statement and her own that Sarah was her mother, but the native habit of transferring parentage to take account of family groupings—it must be remembered not only that Mother Brown and Sarah had lived together for many years, with John Smith, but also that Sarah remained at the Flinders settlement after Mother Brown went off to live again with the sealers—seems a possibile source of a transfer from Mother Brown to Sarah as the mother.

Fanny Cochrane

Writing to the Colonial Secretary in 6 August 1846, Robert Clark, the catechist at the Flinders Island settlement, stated that Fanny Cochrane was born in December 1834, and that Sarah was her mother (CSO 11/26). As Robert Clark came to Flinders in July 1834, this statement would have been made from personal knowledge.

In a list of those attending the settlement school at 31 January 1846, Robert Clark referred to Fanny Cochrane as a 'half cast' (CSO 11/26); and in October 1846, he stated in evidence before an enquiry into affairs at the settlement (CSO 11/27) that she had been named after 'one of Mrs. Clark's sisters'. Dr Jeanneret mentions Fanny Cochrane in several letters and reports (CSO 8/157); on 10 August 1842 she is referred to as the daughter of Sarah by a white man; on 15 September 1842 a list of the aborigines at the settlement includes—

Fanny daughter of Sarah (half caste).
Eugene & Sarah.
Adam son of Eugene & Sarah.

And there are also references in the Colonial Secretary's files to Fanny's schooling at Hobart (CSO 8/72/1642).

Altogether there is little doubt that Fanny Cochrane was a daughter of TARE.NOO.TAIR.ER, that she was a halfcaste, and that she was born in December 1834. However, her father has not been identified; at most, some suggestions can be made as to who he was. It has already been pointed out that Fanny's father is named as Cottrel Cochrane only by implication; but it is possible that he was Fanny's true father and that Mary Ann claimed him as her father in accordance with the native custom by which the most recent parent was regarded as the true parent. Was there a man named Cochrane at the settlement or on the islands in 1834/35? Although the names of the soldiers of the garrison stationed on the island have not been found for this period, no one of this name is known among the convict servants there, or among the sealers. There was a convict named Charles Corkham or Cochran who was one of the crew of G. A. Robinson's boat in 1832, but he seems to have been sent back to the superintendent of convicts at Launceston in November 1832: it is just possible that he was with Robinson again in 1833 on the expedition to the west coast, but very unlikely that he was with him in 1834—the convict records suggest that Corkham was employed in Launceston in 1833, 1834, and part of 1835, and was sent to Port Arthur in July 1935, after which he was probably stationed at Hobart.

There being no known man named Cochrane who might have been Fanny's father, who could have been? There are two pointers to John Smith having been the man. This was the sealer to whom James Parish had sold Tibb when he stole her from her tribe. About June 1831 he began to be employed at the aboriginal settlement, and he was there on and off until 28 July 1834, when he left finally to rejoin the sealers. His duties included those of coxswain of the settlement boat, While there Mother Brown seems to have lived with him; and probably Sarah too, because a settlement record dated June 1834 refers to the trial of one of the convicts there for assaulting Sarah Smith and taking 'indecent liberties' with her. There would have been no strangeness in both Mother Brown and Sarah living with John Smith because a plurality of native women was the rule among the sealers; and the two women had lived with him for many years.

An association between Sarah and John Smith at this time not only suggests that the sealer could have been Fanny's father, but indicates the origin of the name Cochrane. The clue to the latter is to be found in a comment in Ernest Westlake's diary: during his tour of Tasmania he interviewed Mrs Flora Stanton, one of her daughters, in May 1910, who told him that 'Eugene was grandfather's (mother's father's) name a coxswain at Flinders'. Here Eugene, the stepfather, is called the father according to native custom, full parentage having been transferred to the subsequent spouse. And the true father could well have been the coxswain at the Flinders settlement, 'coxswain' becoming 'Cochrane' when pronounced by the natives, who could not deal with the 's' sound.*

Lastly, it should be pointed out that the name Cochrane is only found in the records after 1840, that is, after G. A. Robinson had gone to Port Phillip, so that there was no one at the settlement able to obtain exact information from the natives, not even Robert Clark who, though long associated with them, did not know the native languages well.

Fanny Cochrane married William Smith on 27 October 1854. Their children were—

Charles Edward.
Flora Amelia, m. Alfred Stanton; d. 15 August 1946.
Frederick Henry, m. Joanna Dillon.
Isabella Francis.
Joseph Thomas Sears, m. Matilda Sculthorpe.
Laura Martha, m. John Miller (New Zealand).
Mary Jane, b. 18 October 1859; m. William Miller.
Sarah Bernice Laurel, m. John Miller.
Tasman Benjamin, m. Amy Wells.
Walter George.
William Henry.

Fanny Cochrane Smith died on 24 February 1905.

* It is interesting to note that the notice of Fanny's death in the *Mercury* (Hobart) of 25 February 1905 names her Fanny Corkren Smith. Moreover, note that 'coxswain' is normally pronounced, and abbreviated to 'cox'n' which is a short step to 'Corkren' and 'Cochrane'.

References

Barnard, J., 1890.—Notes on the last living aboriginal of Tasmania. *Pap. Proc. roy. Soc. Tasm.*, for 1889, pp. 60-64.

Bonwick, J., 1870.—*The last of the Tasmanians.* (London). There is also a brief reference in Bonwick's *The lost Tasmanian race* (1884).

Friend, M. C., 1847.—On the decrease of the aborigines of Tasmania. *Tas. J. nat. Sci.*, 3, 3, pp. 241-242.

Longman, M. J., 1960.—Songs of the Tasmanian aborigines as recorded by Mrs Fanny Cochrane Smith. *Pap. Proc. roy. Soc. Tasmn.*, 94, pp. 79-86, 2 pls.

Plomley, N. J. B., 1966.—Friendly Mission. (Hobart)

Roth, H. Ling, 1898.—Mrs Fanny Cochrane Smith not a 'last living aboriginal of Tasmania'. *J. anthrop. Inst.*, 27, pp. 451, 454, pls. 26, 27. Reprinted in Ling Roth's *The aborigines of Tasmania*, ed. 2, 1899, appendix G, pp. lxxxiv-lxxxvii, 2 pls.

Westlake, E., 1908/10.—Manuscript journals. Pitt Rivers Museum, Oxford.

MATHINNA

Mathinna, the little Tasmanian girl who for a time lived with the Franklins at Government House, Hobart, has passed into romantic legend. Before this legend acquires the patina of acceptance it will be as well to outline the little known about her. The principal sources of the following information are G. A. Robinson's journals and papers and the Franklin papers (including copies) in the Mitchell Library, Sydney, and the Chief Secretary's records in the State Archives, Hobart.

Mathinna, or Methinna (Methinné) as the name was sometimes spelt, was a daughter of TOWTERER and his wife WONGERNEEP. TOWTERER was the chief of one of the tribes of south-western Tasmania, probably that inhabiting the country to the south of Macquarie Harbour, and both he and his wife were natives of Point Hibbs. TOWTERER and WONGERNEEP were captured by G. A. Robinson in June 1833, and were sent to the Flinders Island aboriginal settlement. At the time

of their capture they had a young child, a girl, but she died within a few months (at the Orphan School, Hobart).

The English name given to TOWTERER at the settlement was Romeo, that to WONGERNEEP Eveline. TOWTERER died on 30 September 1837, and his widow later married PARLIN, another west coast native, whose wife TINE.DE.BUR.RIC (TOIN.DE.BUR.ER) had died in February 1837. PARLIN'S native name is sometimes written PALLE, PARLEY or PILLA; his English name was Hannibal. WONGERNEEP died in September or October 1840, but it is not known when PARLIN died (he was alive as late as 1845).

Mathinna was born on Flinders Island, probably between July 1834 and June 1835—at the time of the death of her father she was referred to as an 'infant child'; and in a census of the natives at the settlement in June 1838 she was listed as Mary, daughter of Eveline.

Sir John and Lady Franklin visited the Flinders Island aboriginal settlement at the end of January 1838. The following August, G. A. Robinson spent a few days in Hobart on his way to Sydney to discuss a proposal to transfer the natives from Flinders to Port Phillip; and he stayed in Hobart for some weeks on his way back to the settlement. On both occasions he saw Sir John and Lady Franklin. Whether or not the idea of some aboriginal children going to live in their household was discussed during the Franklins' visit to the island in January 1938, it was certainly talked about during Robinson's second visit to Hobart: in his journal for 21 November there is a note that Lady Franklin 'wished me to get a black boy for her'; and on 5 January 1839, just before he left Hobart for the settlement, he 'spoke to Lady F about Adolphus also a girl'. On his return to Flinders and shortly before he left there to enter into his appointment as protector of the aborigines at Port Phillip, Robinson wrote to Lady Franklin. In this letter, dated 10 February 1839, he said—

> In accordance with your Ladyships desire the abl boy Adolphus was forwarded per cutter Shamrock on the 20th ulto under care of Mr Gould to Hobarton together with the new clothing as per list enclosed. The abl girl that I had proposed to your Ladyship is one that I think would not afford the satisfaction I could wish and besides is rather too far advanced in years and as it would be desirable that a companion should be provided for Adolphus and your Ladyship having expressed a willingness to take a second child under your kind and humane protection I have in consequence forwarded Charley a mild and well disposed lad for that purpose. Another orphan boy Teddy is also forwarded which I would respectfully recommend be placed in the Queens School.

Of Adolphus, Charley and Teddy, only the first appears to have stayed with the Franklins for any length of time. When Dumont D'Urville visited Hobart in the summer of 1839/40, Adolphus was running wild in the town whenever he could, associating with the most depraved and corrupt, and preferring the most miserable and most crowded quarters of the town, to be found if not in good company then among gay companions. Jack, as Dumoutier calls him, was then fourteen or fifteen years old; officially he was some sort of groom at Government House (Dumoutier papers, Musée de l'Homme, Paris). He was the son of WY.MUR.RICK and LARRATONG and his native name was TIME.ME.NID.DIC—he was called Timee or Timy by the Franklins. Later the boy joined the crew of the government yacht *Eliza*: in her diary for 11 March 1842, Lady Franklin remarks that he had then been on board about 10 months.

L. W. Miller says of him—

> I had frequent opportunities of observing a native lad, of his age of fourteen years, who was engaged as cabin-boy on one of the colonial vessels, and was pleased to find that he displayed much shrewdness, and a capacity and readiness to learn and do almost any kind of labor. He knew the English alphabet; could spell words of one syllable, and count well. If properly dealt with, I doubt not he would be found to possess no insignificant powers of mind.

G. A. Robinson's remark in his letter of 10 February 1839 to Lady Franklin that he thought the girl he had suggested might not suit, besides being 'rather too far advanced in years', points to someone other than Eveline's Mary as his choice, for she was only about four years old at the time. Probably a definite selection of a girl was not made until Malcolm Laing Smith was appointed commandant at Flinders in April 1839. At any rate, no records have been found which throw any light on the matter, or even point to when the girl arrived at Government House, but there is a comment in Lady Franklin's diary for 3 September 1841 which shows that Mathinna, as she was now known, was there then. At that date she was supposed to be about six years old; and Lady Franklin notes that she had no brothers and sisters alive, that her mother's name was Eveline and her father's name Palle, that is, on her mother's re-marriage parentage had been transferred to the new spouse according to native custom. At this time Lady Franklin was trying to obtain definite information about Mathinna's birth, but there is no indication that she was successful.

There is little authentic record of Mathinna's life at Government House. While there, probably in 1842, her portrait was painted by Thomas Bock, and about this portrait Lady Franklin wrote as follows to her sister Mrs Simpkinson on 14 February 1843—

> Mathinna's portrait is extremely like, but the figure is too large and tall—she looks there like a girl of 12, but is only 7—the attitude is exactly hers, and she always wears the dress you see her in—when she goes out, she wears red stockings and black shoes . . .

Lady Franklin also mentioned the portrait in a letter to Mrs Simpkinson on 8 March 1843, and gives some particulars of Mathinna; and Sir John referred to it in a letter to P. E. de Strzelecki on 2 January 1843. The original portrait was apparently sent to Mrs Simpkinson and its present whereabouts are unknown, but a duplicate of it is in the Tasmanian Museum, Hobart.

Two references to Mathinna in Eleanor Franklin's journal are of interest—

14 September 1841:

> Methinna is 6 years old. Her mother Eveline, father ( ) name Hannibal Port Sorell tribe.
>
> I am good little girl, I have pen & ink cause I am good little girl. I do love my father. I have got a doll & shift & a petticoat. I read. My father I thank the for sleep. I have got red frock like my father. Come here to see my father. I have got sore feet & shoes & stockings & am very glad. All great ( ). Tell my father two rooms ( ).
>
> Unprompted letter to her father.

Port Sorell is a mistake for Cape Sorell, at Macquarie Harbour. Mathinna's letter shows that she was mentally alert, and it is probably in keeping with an age of six under the special environment in which she was then living. (The brackets represent words which have not been deciphered.)

13 October 1842:

> Mathinna's father and mother belonged to the Macquarie Harbour tribe. Her mother's name was WANGENIPP. She was born at Flinders.

The origin of the name Mathinna has not been determined, and she may well have received it only after she entered the Franklin's household. J. P. Gell, writing to his father on 4 November 1841, said—

> (Mathinna) is a very nice intelligent child and a great favourite—she lives with Miss Franklin and her governess and has the manners of a well born child. Her name is Methinna or necklace.

This meeting cannot be confirmed: all that can be said is that MAIR.REE.NER was a word for necklace (G. A. Robinson, journal for 12 November 1830), and that this may be a variant of the name Mathinna. There was also the word META meaning 'sinew' in the eastern dialect, and it was from the sinews of the kangaroo that the natives made necklaces, either forming loops which were loaded with ochre, or stringing small shells on them.

The Franklins vacated Government House in August 1843, and in November left the colony. In July, Mathinna had been sent to the Orphan School; and in February 1844 she went to Flinders Island. John Skinner Prout sketched her when he and Simpkinson de Wesselow visited the island in February/March 1845, and this portrait is in the British Museum. In October 1847 she was again sent to the Orphan School: she was then said to be twelve years old. In August 1851, Mathinna joined the aborigines at the Oyster Cove station, where she died in September 1856. She is probably the Aminia who—

> on the first day of September in the year aforesaid . . . being intoxicated with liquor and laying herself down on her face in mud and water on the road near the Snug it so happened that the said Aminia was there and then choked, suffocated and stifled of which said choking suffocation and stifling the said Amenia there and died.

References

Miller, L. W., 1846.—*Notes of an exile to Van Diemen's Land.* (Fredonia, N.Y.)

Lady Franklin's journal—references to Mathinna have been found in:

Vol. 8, p. 189 (3 September 1841), p. 265 (29 September 1841);

Vol. 10, p. 56 (Feby./March 1842), p. 143 (11 March 1842);

Vol. 11, 1 January 1843, 22 February 1843, 29 March 1843.

BUSTS OF THE TASMANIAN ABORIGINES

Attributed to Piere-Marie-Alexander Dumoutier

When the French exploring ships *Astrolabe* and *Zélée*, under the command of J.-S.-C. Dumont D'Urville, visited Hobart in 1839/40, P.-M.-A. Dumoutier was the expedition's 'préparateur d'anatomie' and 'phrénologiste', and, it seems, also their 'chirurgien auxiliare'. Dumoutier was active during the voyage in modelling in plaster heads of the native peoples met at the various places visited, and there is a large collection of these busts in the Musée de l'Homme at Paris. On the face of it, one would suppose that the Tasmanian material in this collection would have been his work, but there is good reason for doubt in most cases.

The Tasmanian collection in Paris comprises—

1. Buste de BOURRAKOOROO, natif de Ringarooma-bay, comté de Dorset, côte nord de la terre de Van Diemen (Tasmanie).
   MH 904: coll. Dumont D'Urville 58. Atlas: plate 25.
   Comment: no facial hair (? slight moustache); ? young male.
2. Buste d'un natural de la terre de Van Diemen (jeune fille)—HYOLEBOUYER (Lalla-Rook) jeune Tasmanienne de Port Arthur.
   MH 905: coll. Dumont D'Urville 59; coll. Dumoutier 44. Atlas: plate 23.
   Comment: female, aged 20-30.
3. Buste de MÉNALARGUERNA, natif de Oister-bay, comté de Glamorgan, côte est de la terre de Van Diemen.
   MH 906: coll. Dumont D'Urville 60. Atlas: plate 25.
   Comment: male, bearded, ochred hair.
4. Buste de TROUGGARNANNA, femme de WORADDEY, natif de Suliwan Cove, terre de Van Diémen.
   MH 913: coll. Dumont D'Urville 67. Atlas: plate 23.
   Comment: on plinth of bust, at back—TRUCANINNY / wife of WOURADDY / B. Law sculp. / Hobart Town / A.D. 1836.
5. Buste de WORADDEY, chef à l'ile Bruny, canal d'Entrecasteaux, Van Diemanie.
   MH 914: coll. Dumont D'Urville 68. Atlas: plate 23.
   Comment: on plinth of bust, at back—WOUREDDY / aboriginal chief / of V.D.L. / B. Law sculp. / Hobart Town.

6. Buste de Timmey, natif de George River, terre de Van Diemen—Timmey, Tasmanie de Tamar River.
   MH 915: coll. Dumont D'Urville 69. Atlas: plate 22.
   Comment: male, wearing beard but not moustache; age 25-35.
7. Buste de Guenny, port Sorell, Tasmanie—Guenny, Tasmanien de Port-Sorelle, comté de Dorset . . . atlas pl. 22; coll. Dumoutier no. 51.
   MH 916: coll. Dumont D'Urville 70. Atlas: plate 22.
   Comment: male, wearing short beard, but no (? light) moustache (c.f. plate); age 20-30.
8. Buste de Jeune Tasmanien—Voy. de l'Astrolabe et de la Zélée. Coll. Dumoutier. 1874-50.
   MH 1874-50. Coll. Dumoutier.
   Comment: boy, aged 10-12.

In the above list the entry on the registration card of the Musée de l'Homme is given first, to be followed, after the dash, by any information given on the label associated with the bust, or written on the bust, which differs from that on the registration card.

In the library of the Musée de l'Homme there are some of Dumoutier's papers, and the busts are mentioned in them. It should be noted that the voyagers spent only a short time in Hobart, and that for most of the company this was in two periods, the first from 12 December 1839 to 1 January 1840. and the second from 17 to 25 February 1840; furthermore, that the ships called at Hobart largely because of illness on board, and that the medical staff particularly were very fully occupied tending the sick during their stay in port. The only excursion of any distance seems to have been a brief visit by a small party to Launceston, and another to Port Arthur by some of those remaining in Hobart with the sick during the absence of the ships in antarctic waters from 1 January to 17 February.

Dumoutier tells us that the only aboriginal living in Hobart at the time was a boy 14-15 years old in Sir John Franklin's household (this would have been Adolphus—see notes on Mathinna) and some children at the Orphan School (five full-bloods and several hybrids); the only others were the captives on Flinders Island. It is strange that Adolphus should be mentioned and not Mathinna, a much published young person, and so one wonders how much direct contact Dumoutier had with Government House: perhaps little, if any.

Of the natives named on the busts, several can be identified. There is no doubt about WOORRADY and TRUGERNANA, and little about MÉNALARGUERNA native of Oyster Bay (= MANNALARGENNA) and Timmey native of George River (= MAUL.BOY.HEEN.NER); but difficulties arise with BOURRAKOOROO, HYOLEBOUYER Lalla Rookh jeune fille, and Guenny. The bust of Guenny (= Jenny) is that of a man; she was a young woman, the wife of Timmy. The label 'HYOLEBOUYER Lalla Rookh jeune fille' seems confused and may be a combination of two labels, one 'HYOLEBOUYER', and the other 'Lalla Rookh jeune fille'. HYLOEBOUYER has not been identified, but the name may be an error of transcription for TANLEBOUYER (= TANLEBONEYER) an elderly woman; Lalla Rookh was a name given to TRUGERNANNA, who had no recorded name resembling HYLOEBOUYER. BOURRAKOOROO native of Ringarooma Bay has not been identified. To make a rather wild guess, the bust of 'HYOLEBOUYER Lalla Rookh jeune fille' is that of Jenny; the bust of 'BOURRAKOOROO' that of TANLEBONYER; and the bust of 'Guenny' that of BOURRAKOOROO, who has not been identified.

The remaining bust, that of the 'jeune Tasmanien' (8), is perhaps a portrait of Adolphus. If so, it is the only Tasmanian bust which Dumoutier modelled from life, because at the time of Dumoutier's visit to Hobart all the natives identified above were either dead or with G. A. Robinson at Port Phillip. MANNALARGENNA had died at Flinders Island on 4 December 1835, TANLEBONEYER in Hobart on 1 May 1835, and Jenny at Flinders Island in February or March 1839; WOORRADY, TRUGERNANNA and Timmy were at Port Phillip.

What then was the source of Dumoutier's models? There are two pointers to this in the records. The first of these is a comment by Dumoutier—

> Sans parler de l'assistance cordiale et généreuse que M. le docteur Bedford a donnée aux malades françaises, il a été aussi très favourable aux travaux de l'expédition, en donnant un crâne de naturel de la terre de Diemen, et en permettant de recueillir des empreintes de la physionomie d'hommes et de femmes de ce pays.*

The second pointer is a statement by Dumoutier that in Sir John Franklin's drawing room there were paintings in natural size, bust showing dress, and a collection of miniatures illustrating the customs and appearance of the natives; and that as a result of his seeing them, Dumont D'Urville had bought examples of two of the busts (Law's busts of TRUCANINNY and WOUREDDY) and had copied the miniatures (Bock's portraits of the natives).

So far as known, there were two people in Hobart at the time from whom busts might have been obtained, Benjamin Duterrau and Benjamin Law. Duterrau is known to have made a number of basreliefs of the natives, and 'casts' of Timmy, WOUREDDY, TRUGERNANNA and MANNALARGENNA, at least (ref.: catalogue of the sale of Duterrau's work, by Elliston, in Hobart on 27 August 1851). However Law seems more likely on stylistic grounds, although he is not known to have modelled any heads of Tasmanians other than those of TRUGERNANNA and WOURRADY. However, he certainly executed a number of other busts not now existing. Sir John Franklin and Dr Bedford may well have had copies of the work of both men.

* Quite apart from the cordial and generous assistance given by Dr Bedford to the sick Frenchmen, he has also been very well disposed towards the work of the expedition, presenting a skull of a native of Van Diemen's Land and permitting the gathering of casts showing the physiognomy of the men and women native of this country.

References

DUMONT D'URVILLE, J. S. C., 1841/54.—*Voyage au Pole Sud et dans l'Océanie sur les corvettes l'Astrolabe et la Zélée.* Histoire du voyage, vols. 8 (1845), 9 (1846). (Dumont D'Urville) Anthropologie, Atlas, plates 22, 23 and 25. (Dumoutier)

B. LAW SCULP.

Benjamin Law and his wife Ellen arrived at at Hobart Town in the *Sarah* on 14 February 1835. Law was then about twenty-seven years old. The *Sarah* carried immigrants, who were in charge of Mr and Mrs Charles D. Logan, the same Logans who set to music one of the songs of the Tasmanian aborigines a year or so after their arrival (see G. A. Robinson's journal for 22 October 1836).

Law was described, with other assisted emigrants as 'of the agricultural class' in the papers relating to his immigration (Tasmanian State Archives CSO 1/787/16814) but this was probably no more than a device to qualify him for an assisted passage: he does not seem to have engaged in any agricultural pursuits in Tasmania and apparently all his life there was spent in Hobart. Backhouse (journal 23rd 8 mo 1837) tells us that Mr and Mrs Law were superintendents of one of the infant schools. In 1836 they were living at 76 Murray Street; and in 1842 in Collins Street, where Law had a hardware store, near the Independent Chapel. Some time later Law became insolvent. He was still living in Hobart in 1851.

Benjamin Law is of particular interest because of his sculpture. Two of his busts are very well known, those of the Tasmanian aborigines WOORRADDY and TRUGERNANNA; but there are also records of other busts, although none of these others seem to have survived. The following is a list of his work of which there are records:—

1. 'WOUREDDY an aboriginal chief of V.D.L.' Issued September 1835. Price £4.4.0.
   Sources: advertisement dated 7 September in *H.T. Courier* of September 1835; also notices in other Hobart newspapers of the period; Ross's *Hobart Town Almanack*, for 1836.
2. 'TRUCANNINY wife of WOURADDY.'
   Issued October 1836, 'either in bronze or stone colour'.
   Sources: *H.T. Courier* of 7 October 1836. (To his advertisement Law added a footnote—'Likenesses modelled and busts executed in marble, bass-relief, &c.').
3. Dr. James Ross.
   In the *H.T. Courier* of 17 August 1838 there is a report that Law had a cast made of the face of the late Dr. Ross, from which it was hoped a bust would be made for the Mechanics' Institute, in his memory.
4. DERRIMUT and BETBENJEE.
   The Port Phillip natives DERRIMUT (DERAHMAT, DERRAHMERT) and BETBENJEE (BAITBAINGER) had been brought on a visit to Hobart by J. P. Fawkner in October 1836, to seek the return of their wives who had been abducted by the sealers.
   Sources: James Backhouse, journal for 23rd 8 mo. 1837; *H.T. Courier*, 16 September and 7 October 1836; Daniel Bunce (1857) *Twenty three years wanderings in the Australias and Tasmania*, pp. 60-61; N. J. B. Plomley (1966) *Friendly mission*, p. 938, note 12; Tasmanian State Archives, CSO 5/19/384. (A portrait in oils of the chief DERAH MAT (DERAHMERT), by Benjamin Duterrau, is in the Dixson Library, Sydney. It is dated 5 October 1836. Duterrau also painted BAITBENGER: see catalogue of the sale of his pictures and sculptures, 27 August 1851).
5. George Augustus Robinson.
   Sources: James Backhouse, journal for 23rd 8 mo. 1837; G. A. Robinson, journal for 7 October 1836 and 17 December 1838; *H.T. Courier*, 7 October 1836; GAR to Gamaliel Butler, 22 September 1837 (Robinson papers, Mitchell Library). (Robinson had a sitting for this bust on 1 August 1835.)
6. James Pascoe Fawkner.
   Sources: James Backhouse, journal for 23rd 8 mo. 1837.

BOCK'S PORTRAITS OF THE TASMANIAN ABORIGINES

It seems inevitable that what one thinks to be the last fullstop is no more than the prelude to a new paragraph. So it has been with the study of Thomas Bock's portraits of the Tasmanian aborigines. A paper which seemed complete had just been set in print when additional material came to light, making necessary a re-assessment of some of the conclusions reached in the original paper (Plomley, 1965). Now, still more has turned up

In the *Mercury* (Hobart) for 21 August 1884 there is printed a letter from Henry Dowling entitled 'Bock's aborigines'—

> In 1837 I saw the original sketches made by Bock, at the instance of Lady Franklin, and was struck with their great truthfulness and merit, in marked contrast to those of M. Dutterreau, and, on application to her Ladyship, had the pleasure of gaining her consent that I should have replicas. This was in the latter part of 1837.
>
> Mr. Bock made no such pretensions to an art career as M. Duterreau, but his genius and ability were very superior.
>
> With Lady Franklin's appreciation of art it was only natural to her to employ Bock, and not Duterreau. In 1836 I saw in Bock's studio several portraits of residents in Hobart, which were very creditable indeed.
>
> As to the "native" portraits I had ample means of forming a judgment. Besides frequent opportunities of seeing "Robinson's Blacks", as they were termed in 1832, and of studying their physiognomy, I had the unusual opportunity of seeing specimens of the "wild natives" on the occasion of the inquest on Captain Thomas and Mr Parker, in 1831, when "Jinny", as she was termed at the time, and is designated in Mr. Fenton's book, was examined as a witness for upwards of an hour, during which time the supposed male murderers,

and the witness, stood before the jury, just in their native condition; and I cannot be mistaken either with respect to their physiognomy or their colour. Duterreau represents them as black, as "black lead polished". Bock gives the proper colour, when they were besmeared with grease and red ochre, as they came in from the bush. (See M. Bellefin's experience, p. 20, Fenton's Hist.) Naturally they were really copper-coloured, as it is termed.

The very creditable chromo-lithographs of our new history are rather light, but that may be traced to the fact that Bock's drawings having been exposed under glass to the rays of the sun at a Ballarat Art Exhibition, for which they were lent by me, faded considerably.

These portraits formed the study for Mr Robert Dowling in preparing the composition of "The Natives", presented by him to the Town of Launceston and now in the reading-room of the Mechanics' Institute.

Any of your readers who may be curious in such matters who may be disposed to examine the cabinet of Bock's portraits in the possession of the Government, will note that if any additional verification of the originality of Bock's work is needed it may be found in the interesting duplicates, in profile, in neutral tint, amongst Bock's, made expressly by direction of Lady Franklin, so that the peculiar formation of the lower jaw of some of the Tasmanian aborigines might be ascertained in any not to be seen in the principal portraits.

There are several points of interest in this letter. The first is the statement that Dowling had seen 'the original sketches made by Bock, at the instance of Lady Franklin'. Whatever Dowling might have meant by this ambiguous statement, it has certainly been taken to mean that Bock painted the original portraits for Lady Franklin. It is obvious that he did not (Plomley, 1965).

The second point of interest lies in the information that the 'replicas' which Dowling obtained from Bock, with Lady Franklin's consent, were used not only by his brother Robert when painting his group portraits of the Tasmanian aborigines (Plomley, 1961), but also in the preparation of the lithographs in 'our new history', that is, James Fenton's *History of Tasmania* (1884). Incidentally, Henry Dowling's remark that the portraits had faded during exhibition at Ballarat is doubly interesting: it shows why portraits prepared from them were lighter in tone than the 'copper colour' of the originals, so that neither Dowling's series nor the copies based upon them are of value in designating the colour of the skin in the Tasmanians; and it provides another link between the Dowlings and Victoria (Plomley, 1961).

Thirdly, the identification of 'Jinny' (= Jenny) as Sydney now seems fairly definite (Plomley, 1966, appendix 6).

Lastly, there is now a case for re-examining the Bock collection in the Tasmanian Museum. The set of portraits, full-face and profiles, which was presented by the Government in 1889, were described as facsimiles; and technically they seemed to be Alfred Bock's work, so that they were ascribed to him (Plomley, 1965). Yet, Fenton's statement that his lithographs were prepared from the portraits in the possession of the Government, and Dowling's remark that Fenton's lithographs had been prepared from the portraits which he had obtained from Bock with Lady Franklin's approval, clearly link the two sets. Did the word 'facsimiles' mean 'replicas' made by the original artist, rather than copies by another hand? Was my technical identification wrong—the Tasmanian Museum series was not examined by Messrs Croft-Marray and Reynolds?

To complete this note, the whereabouts of two more of Thomas Bock's portraits of the Tasmanians can be recorded. These are in Dixson Library (Sydney), in the 'Thompson portfolio' purchased by Sir William Dixson in 1912 from Angus and Robertson. The portraits are clearly Thomas Bock's work: thay have A 1/2 inscriptions. The natives portrayed are WOUREDDY and TRUGGERNANA. Attention is also directed to a note in Lady Franklin's journal for 22 September 1840 (vol. 5, p. 160) that "Mr. Bock is painting the aborigines in my possession, for Mr. Ashburner".

References

PLOMLEY, N. J. B., 1961.—Pictures of Tasmanian Aborigines by Robert Dowling. *Bull. nat. Gal. Vict.*, 3, pp. 17-22.

————, 1965.—Thomas Bock's portraits of the Tasmanian aborigines. *Rec. Q.V. Mus. Launceston*, 18, 25 pp.

————, 1966.—*Friendly mission.* (Hobart)

NEW NORFOLK IN EVOLUTION

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(With two text figures.)

ABSTRACT

An account is given of the town of New Norfolk, Tasmania, from its early colonial beginnings until the present day. The town owes its foundation to Governor Macquarie, its continuation to a productive immediate hinterland and the heritage of an early administrative function, and its present position, as the State's sixth ranking town, dominantly to one industry—newsprint manufacture.

INTRODUCTION

Late in the spring of 1811 Lachlan Macquarie, Governor of New South Wales, viewed the three-year-old settlement of New Norfolk, Van Diemen's Land, from the vantage point of the elevated Government farm on the south bank of the Derwent River. Behind him, between this place and the colony's main settlement at Hobart Town, the river had forced its way between two mountains, but upstream the valley broadened. Fresh water was at hand, and for two miles above the Government farm the river was navigable. On the north bank were the many small farms of the Norfolk Islanders, but there were none here on the southern side; from the river the land rose over one hundred feet to a flat, basalt capped river terrace which terminated half a mile upstream against a high wooded hill. In his 'Journals' Macquarie wrote 'This situation appeared to me so eligible and so remarkably well adapted for a township, being twenty miles only from Hobart Town, that I have determined to erect one here for the District of New Norfolk . . .'.

IN THE BEGINNING

The Norfolk Islanders

In the same year that Van Diemen's Land was first settled initial moves were made to relocate the settlers of Norfolk Island. First occupied in 1788, the island became a prison for the worst criminals and doubly convicted of New South Wales, but also, and increasingly, it was a home for free settlers. Opinions differed as to the island's potential, but factors against its continued maintenance were the isolation, the agriculturally difficult climate, and a population (dominantly of ex-soldiers and sailors) largely ignorant of the arts of husbandry. In 1803 Governor Phillip was instructed to move some of the settlers to Van Diemen's Land, but his successor (King) and the Island's settlers were equally unwilling to see the order fulfilled. By the end of 1806 there were still seven hundred people on the Island, over three-quarters of the total of 1803, and nearly all were free settlers. However, the rate of evacuation was considerably increased in the next two years as the British authorities, impatient with colonial tardiness, issued new orders for removal, offering favourable terms of transfer with respect to land, homes, and immediate requirements for provisions and labour in Van Diemen's Land. By October 1808, 554 Norfolk Islanders had arrived. Of these only twenty-three were convicts, and nearly half the remainder were children. If any new arrivals were satisfied with the terms of their relocation they were soon to be disillusioned. The land promised was available but the other promises, so blithely made in far-off Britain, could not possibly be met. The influx more than doubled the population of Van Diemen's Land at a time when those already there were struggling to survive. The more resourceful of the Islanders accepted what was available and set to building for themselves, but most were resentful of the situation; many bartered their land for easier living in the town, eventually as Walker records, to 'sink out of sight in poverty and wretchedness'.

The founding of New Norfolk

The ship 'Sydney' brought the first of the Norfolk Islanders to Van Diemen's Land in 1805. On board was the Irish exile Joseph Holt who, on arrival in Hobart Town, was despatched by Governor Collins to look for a suitable place for the newcomers to settle, in the Derwent area. Holt's exploration apparently probed little further than the present site of New Norfolk, and he reported to Collins that although there was land for good farms it was not of sufficient extent for a large settlement. Nevertheless the district became the home of most of the Islanders who took up their land in 1807 and 1808. They were the pioneers: when Lieutenant Laycock passed through the region in 1807 the lands were unoccupied, but in May the following year the Revd Robert Knopwood was able to record a trip up the Derwent in the course of which he was the guest of one of the first New Norfolk residents.

John Oxley reported on the settlement as it was in 1810:

> A considerable portion of the Norfolk Settlers have chosen to settle on the lands at the Upper part of the River; their district is named New Norfolk and is represented as being a most delightful Country, the land contiguous to the Banks of the River being extremely fertile and not liable to flood; extensive plains and rising Grounds afford Pasturage for any

> Number of Cattle; a number of small rivulets, intersecting the Country in every direction, is an advantage the Country near the Sea Coast is deprived of; the main River, being navigable for Boats for a considerable distance, affords an easy Communication with the principal Settlement. These Lands have not been settled for more than 18 Months, and appearances are so favourable as to Warrant the Expectation that with proper Care and Management a short Space of time will preclude the Necessity of further Importations of Grain . . .
>
> (Historical Records of Australia, Series 111, Vol. 1)

The following year the district was visited by Lachlan Macquarie, new Governor of New South Wales. By this time a Government farm had been established on the vantage point from which Macquarie chose the town site. During his visit he inspected the farms of the district, which extended for four miles along the north bank of the river. Of their condition he wrote 'the soil . . . in general is excellent and there is at present every appearance of a plentiful and abundant harvest; but the houses of the settlers are mean and badly built, and themselves miserably clothed'. According to the historian West 'their frail dwellings soon exhibited all signs of decay, and their ground was exhausted by continual cropping'.

New Norfolk, then, held the Colony's greatest concentration of free settlers, as at this time the Norfolk Islanders constituted nearly half the total population, and most of the remainder were convict. And, beyond the two main centres of Hobart Town and Launceston, it was the first district in the Colony to be closely settled.

The village of Falls

The rural population of New Norfolk, fairly dense in relation to that of Van Diemen's Land and New South Wales generally (the average land grant to Norfolk Islanders was about forty acres), would have given rise to urban development without Macquarie's declaration of a town site, and even in the face of this a small village developed near the banks of the Derwent at the place now known as Lawitta, but then known as The Falls, or simply, Falls. As the old name suggests (albeit with exaggeration) bedrock here broke the surface of the river, establishing the head of navigation. This factor, and its location central to the rural community, made the site a more logical one for a village than that of the planned town, at the downstream periphery of settlement. The village is named on a chart of Van Diemen's Land published by Joseph Cross of London in 1838, but there is little recorded of it; most attention is given to 'Elizabeth Town', as New Norfolk was first known, which in accord with Macquarie's desires developed as the administrative centre of the district. The only description found of the village is in J. Syme's 'Nine Years in Van Diemen's Land', written in the 1840s:

> '. . . though it has not the honour of being a town . . . we find many shops for the ordinary articles of tea, sugar, tobacco, rum and slop clothing, a medical resident, and some approximation to a country village at home'.

There are earlier references to a ferry across the river at this point, although there was also one at Elizabeth Town, and when in the mid 1820s plans were first mooted for the construction of a bridge to serve the district, the Land Commissioners investigating the matter were unanimous that it should be at Falls. However with the extension of rural development further up the Derwent, and amalgamation of some of the early New Norfolk small holdings, demands on the little village declined in favour of the administrative centre, Elizabeth Town. In 1840-41 the bridge was eventually built, but it was at the town, not at Falls. Some thirty-six years later the village still had a school, an inn, and the chapel, but in the 1880s its functions ceased, and the name of Falls was heard no more.

Some early town plans

Following the selection of the site for Elizabeth Town in 1811 Macquarie was concerned that his requests be carried out. The next year the deputy to the Surveyor-General of New South Wales, James Meehan, was instructed in the course of a survey to mark out the site of the town. He came to Van Diemen's Land in 1813 to carry out the task, and a plan was produced the following year. The earliest plan still available was produced by G. W. Evans about 1824 (signed, but not dated); the streets were marked out and named, but both names and street pattern were later changed. This plan probably never existed on the ground: the rigidity of the grid was not practicable on the steeper slopes of the terrace, but also an open square, four times the size of the present Arthur Square, occupied a wastefully large proportion of the flat land. Of the few buildings shown on this early plan the schoolhouse was begun in 1823 and Turriff Lodge, the Governor's retreat, was built some time prior to 1817. Accompanying a painting of this by J. Lycett is a note that it 'was frequently resorted to by the late Lieutenant-Governors Davey and Sorell, as an agreeable relaxation from the bustle and fatigue of public business.'.

Another plan of the town was produced in 1833 by W. S. Sharland, an Assistant Government Surveyor of the time. The differences between this and the earlier plan are quite profound, the first real urban development having taken place in the interim. With the exception of Bridge Street (which was constructed soon after the bridge was proposed in 1836) the plan, within the 1833 limits, has remained almost unchanged (see Figs. 1 and 2).

Town growth in the Colonial context

Development of Van Diemen's Land was slow until about 1820, partly because of the difficulties encountered in establishing agriculture under foreign conditions but dominantly because of the isolating effects of the Napoleonic Wars. By 1820 however the way was cleared for progress. The realization of a wool market in Britain coincided, and was associated, with a changed attitude among British capitalists. Once again they were seeking outlets for overseas investment, and for the first

time the Australian colonies were seen as having possibilities. Government immigration policy had also changed: now capitalist immigration to Australia was favoured, to absorb the convict workforce, and regulations were designed to this end. The result was a large-scale granting of land to immigrants who could afford proof of capital, and the 1820s saw rapid occupation of new territories. The town of New Norfolk, under official sanction, at last began to develop: in 1825 the 'Hobart Town Gazette' reported—

> 'We understand with much pleasure that New Norfolk, the favourite retirement of Colonel Sorell and other distinguished characters, is rapidly becoming improved. The Church . . . has been considerably enlarged. Several most excellent buildings have been commenced . . . Everything therefore indicates the rapid rise into special eminence of that very beautiful town; and that ere long it will constitute a flourishing mart for at least one fourth of the Colony we think with others is a supposition far from improbable.'.

By 1831 there were some substantial buildings in the town, including 'several excellent private dwellings'. Among these were Woodbridge, built by W. S. Sharland in 1827, and Hallgreen, home of Robert Officer, first Government Medical Officer for the district. Both still stand above the south bank of the Derwent, a beautiful location early favoured by the more wealthy residents.

This decade of development saw considerable official attention focused on New Norfolk. Governor Arthur was anxious that it should become the chief town of the Colony, and although this grandiose scheme was coldly dismissed by British authorities the town did become the centre for the Colony's first Police District, and on this account a number of public buildings were required. These included soldiers' barracks and convicts' quarters, and in 1827 work on the hospital was begun, continuing over some years as further extensions were required. In 1832 when Governor Arthur ordered all Government invalids to be transferred there it became the Colony's military hospital, and yet more extensions were needed when a few years later provision was made for mental patients.

The building boom of the late 1820s and early 1830s both public and private (many buildings of a more modest nature were constructed on the south side of High Street—see Fig. 1), testifies to the rapid development of the Derwent Valley in general and New Norfolk in particular. The 'Hobart Town Courier' of April 14, 1832, refers to 'that thriving settlement', and the stage coaches (the first between towns in the Colony) which had infused a 'vivifying spirit of circulating activity throughout the district'. By this time too a regular steamer service was operating, invaluable to the settlers in the interior of the district in forwarding produce to market with a certainty formerly unknow.

The circumstances which so favoured the town in this period were not to continue for very long after. The bridging of the Derwent in the early 1840s had little effect on the town's growth, indicating the slower tempo of the times. Apart from the bridge toll-house no building was generated on the north bank; even fifty years later the only buildings on this side of the river (with the exception of a few farm houses) were those in connection with the railway.

RECESSION AND RECOVERY

The Van Diemen's Land scene

This state of reduced activity was symptomatic of all Van Diemen's Land, and was the unrecognised herald of stagnation. British immigration policy had again changed, this time in response to the influence of Wakefieldian ideas, and the Ripon land regulations of 1831 were the result. Hereafter land was to be released by sale only, grants being allowed only if already promised. Governor Arthur favoured the old grants system and took full advantage of the 'grants promised' loophole, with the result that more land was granted than sold in the following decade. But land was a limited resource, and with decreasing opportunities in the island and increasing mainland competition the Colony began to lose attraction, not only to immigrants but to some of the early settlers and the native born as well. Until this time the general trend of Van Diemen's Land fortunes had been upward, with markets both in Britain and mainland Australia. Wool was the major overseas export, but in intercolonial trade wheat was the chief item. Until the 1840s Van Diemen's Land was the 'Granary of Australia', but from this time it suffered increasing competition from South Australia to the extent that wheat growing was no longer profitable, except for the small and decreasing local market, and with the best land alienated by grants decline of the Colony was imminent.

The mainland gold rushes of the early 1850s greatly speeded migration from Van Diemen's Land, leaving a residue of the extremes of rich and poor. The effects of this, plus loss of markets and lack of economic opportunity, were obscured at first by great demands from the goldfields for primary produce, but with some stabilization there after the initial rushes this demand sharply slackened and the full effects of the Colony's economic plight were realized. Even when gold no longer attracted immigrants the advantages of the developing colonies on the Australian mainland were enough to keep Tasmania, as it was by now known, well in the background. The depression, deepest in the first decade, cast a blight over the land for twenty years until mineral discoveries, and agricultural pioneering in the north and north-west, at last brought promise of a brighter future.

Change in the New Norfolk region

The depression was particularly marked in the south of the Colony, and New Norfolk's position as a leading district was well and truly lost, but even so it fared better than other old agricultural districts around Hobart Town. The pastoral districts further up the Derwent and along its tributary the Clyde remained throughout the lean years a prime wool producing region, and closer to New Norfolk agricultural pursuits of a different kind were soon to bring new life to the district.

Hopgrowing, which had been carried out on a small scale in the Derwent region from the 1830s, became a much more tenable occupation with the success of experiments by the enterprising Derwent family of Shoobridge. With this stimulus hop acreage increased markedly from 1864 along the river flats and low terraces around and upstream from New Norfolk, and further strides were made after 1870 when Tasmania's natural advantages in this field were shown to outweigh the disadvantages of Victorian protective tariffs. In these years orcharding too became a commercial proposition, promoted in the Derwent by the same landholders. Original markets were in free-trading New South Wales, but with the introduction of refrigeration in the 1880s export overseas also became possible.

Revival of agriculture in the New Norfolk region had little marked effect on the development of the town: it grew, but only slowly. When the ' Traveller through Tasmania ' passed through in 1885 he was impressed, as visitors usually are, by the beauty of the river, where ' somewhat antiquated houses lay more or less hidden among bright and pleasant garden shrubberies '. But in the main street he found very few buildings that could be called ' handsome or imposing '; away from the river it was not much of a town. By the end of the 19th Century most building was still contained within the area laid out in Sharland's plan, although there was the first suggestion of ribbon development along the Glenora and Lachlan roads west and south of the town.

The Lachlan Park Asylum

From 1848 the one-time military hospital was exclusively for mental patients, and catered for the entire Colony. As the island's population increased so did the demands on the hospital, and new buildings were added in the late 1880s and early 1890s. In the new century more land was acquired for hospital purposes, and by 1921 nursing staff accounted for eight per cent of the town's population, and probably about twenty per cent of the workforce. Thus although the institution created little direct demand for local business (supplying many of its own services and provisions), in terms of income generated it was a vital factor in the prosperity of the little town.

Country town

The asylum was evidently an important factor in town growth from about 1890, but earlier than this the economic life of the town had received something of a fillip little reflected in physical expansion. From 1868 to 1890 there was some increase in retailing and other service functions but little in the town to account for this. The stimulus came from the immediate region, where horticultural practices were revolutionizing the scene and reviving the economy. Settlements and farms around New Norfolk were heavily dependent on the town; the nearest villages to offer the most basic services were Macquarie Plains (Gretna) and Glenora, twelve miles away. These, and the more remote valley settlements, probably also relied on New Norfolk for their less frequent demands.

Directories of the time indicate increases in retailing outlets in the new century, particularly in the 1920s. From 1921 to 1933 the town's population increased by six per cent (see Table 1), and the surrounding rural areas also increased their demands. Contrary to the prevailing situation in Tasmanian country districts the population of localities around New Norfolk was on the increase.

Prior to 1921 the only processing or manufacturing establishments at New Norfolk were of a very rudimentary nature, or very short lived. The only industrial activity which endured was sawmilling, which was pursued rather intermittently and on a small scale. However 1926 saw the establishment of the Pioneer Woodware Company's peg factory, the first industry in the town with a market beyond its own area, and in the 1930s some other small scale industries also began operations. Improvements in transportation, communications, and mechanical processing were making country town industry more feasible.

Post-1920 developments were reflected in physical expansion of the town. Infilling of the old town area continued, and ribbon development increased along the Glenora and Lachlan roads and was quite strongly initiated on the Hobart road, on the other side of the rivulet from the town. There was also considerable building on the eastern slopes of Peppermint Hill, and a few town houses were built on the northern bank of the river. In view of developments in the town, and with evidence of buildings constructed in this period, it is probable that there was an increase in the rate of population growth in the 1930s. Unfortunately the extent of this is not known as there was no census between 1933 and 1947, and at this latter date figures were considerably influenced by post-1940 development. However the years between the wars were years of growth, only slow perhaps when compared with the changes of the next twenty-five years, but at least introductory to them.

THE INDUSTRIAL ERA

Industry and population

The small-scale enterprises established at New Norfolk in the 1930s were symptomatic of a new trend to industrial expansion in Tasmania. A few relatively large-scale industrial enterprises had come into production in the last years of World War I, but in the 1930s more were proposed, and these included the establishment of the Australian Newsprint Mills on the Boyer Estate, near New Norfolk.

The coming of the industry in 1938 meant not only the establishment of a large industrial plant on New Norfolk's doorstep but also the creation of a new Company village, Maydena, at the fringe of the forest country high up the Tyenna Valley. At both centres the activities of the industry led to, in fact demanded, an infusion of new blood. This influx of newcomers was most marked in relation to Boyer employment, as the high demand for skilled and experienced workers could not locally be met. In the early years of its existence most of the administrative, technical and office staff was recruited from areas beyond New Norfolk and its surrounding country districts. The need for this has lessened over the years, yet as late as 1965 only half the Boyer workforce had lived in the region prior to association with ANM. At this time thirty per cent were drawn from other Tasmanian

towns and cities, and collectively the other Australian States and countries overseas provided only six per cent.

Industrial development at Boyer has been carried out in three stages: that of initial construction (1938-1941), that involving construction of the second paper machine (1947-1951), and the current construction programme, providing a third paper machine, begun in April 1966 and with completion expected by January 1969. Each phase has brought an increase in town population, new housing construction, and increased commercial and service activities. In turn these latter have also provided opportunities for employment, drawing more people from surrounding country areas.

Town population since 1921 has increased as follows:—

TABLE 1

Year	Town Population*	Intercensal increase (%)	Annual rate of increase (%)
1921	1464	....	....
1933	1555	6.4	0.5
1947	2275	46.3	2.8
1954	3989	75.3	8.3
1961	4682	17.4	2.3
1966	4868	4.0	0.6

* Town population excludes mental hospital patients.

Notable is the low rate of increase in the 1961-1966 intercensal period. The census was taken before the current expansion programme really got under way; in the first twelve months following the last census, town population (including the asylum) increased from 5775 to an estimated 6308 (an increase of nine per cent).

Lachlan Park expansion

Another factor in population growth has been the increased employment at Lachlan Park of nursing staff and other workers. Since 1954 (the earliest year for which relevant records are available) total employment here has increased by thirty per cent. In contrast with the industrial workforce most employees are native to New Norfolk or its immediate region. This increase in employment has been associated with considerable building activity, new land having been acquired for expansion. The early hospital buildings, some over one hundred years old and most dating from last century, have long been outmoded and inadequate, and nearly all have now been demolished and replaced by modern, efficient structures. Also many new homes have been constructed for employees near the new hospital buildings, an effort to attract more staff, nursing staff especially.

Residential development

Most of the residences in New Norfolk today are of relatively recent construction, more than half having been erected since 1940 to accommodate the increase in population. The nature of this recent development is markedly different from that which preceded it. Previously homes had been built piecemeal, here and there, by private individuals, first filling in the old town areas and then creeping along the main roads and up the hill slopes. In contrast post-1940 construction has been dominantly through the development of housing estates, financed by industry and government. There has also been some private development along traditional lines, and that already mentioned at Lachlan Park, but this constitutes only a minor part of the whole.

Australian Newsprint Mills has been the largest contributor, home-building booms accompanying periods of increased industrial activity. By 1965 the company had built 345 houses, nearly all on its large subdivision on the northern side of the river, and the current expansion programme has involved the construction of 130 homes on a new estate adjacent to this. Housing Department development has also recently taken place in New Norfolk North. Government housing in New Norfolk dates back to the early 1950s when the Agricultural Bank built 90 structures near Kensington Park. Since then the Housing Department has added about 150 homes, near the first estate, at Tynwald, and most recently at Fairview (see Fig. 2).

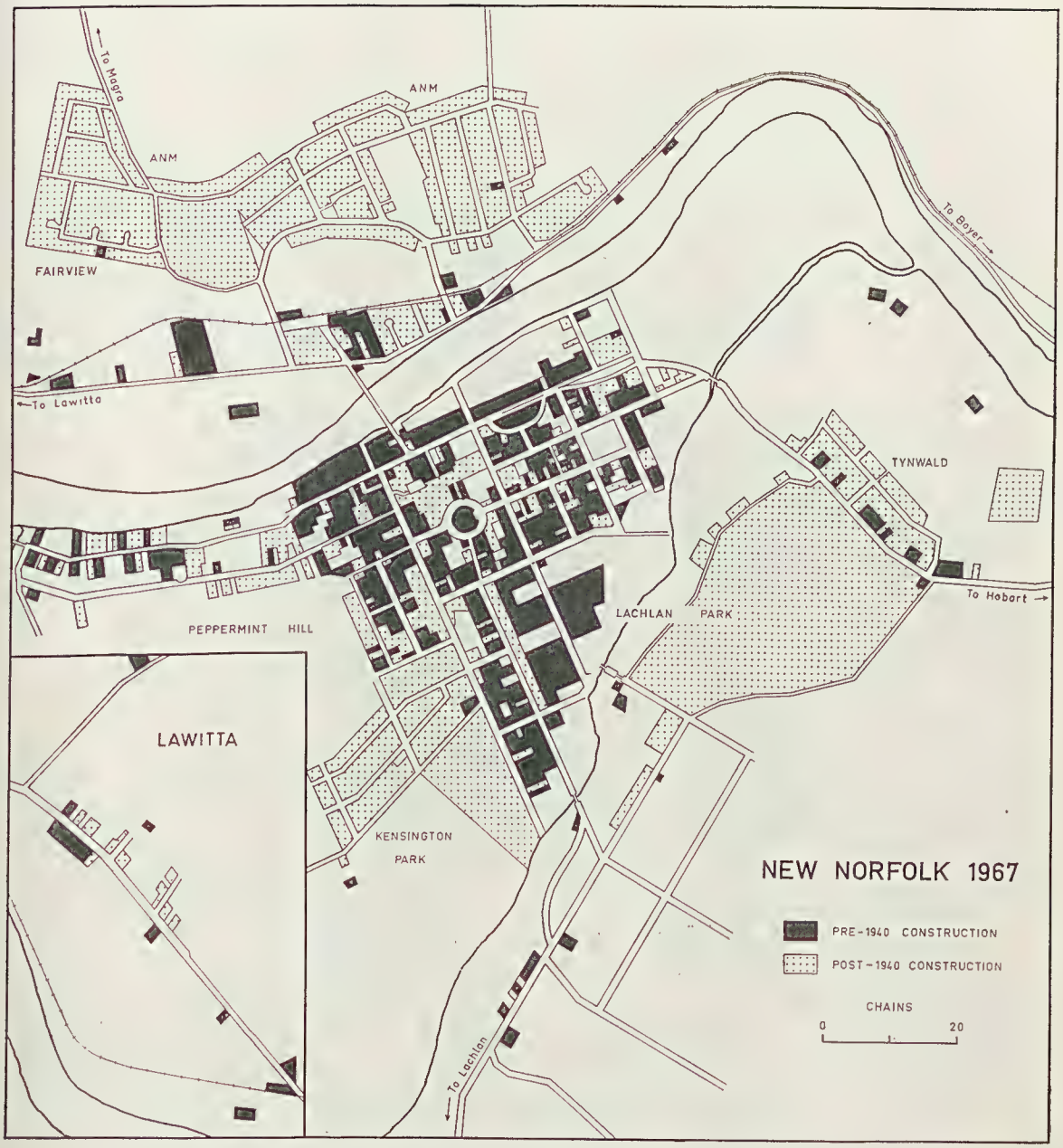
Commercial and service functions

Residential expansion in the town since the coming of ANM is plain to see, but far less evident is the increase in commerce. High Street, in the old town, does have quite a range of shops, yet commerce is underdeveloped for a town of this size. A prime reason for this is the proximity of Hobart. Nevertheless there has of course been a considerable increase in business in the last twenty-five years. Increase in retailing and other services has been closely associated with increases in population. The greatest rate of town population growth was in the 1947-1954 period, and in these years there was also an increase in the rate of functional expansion, though this was greater in the years immediately following. Decline in the rate of population growth from 1954 to 1961. and more so in the next intercensal period, has its parallel in a decreased rate of functional growth from about 1960.

Expansion in retailing involved the opening of a number of new shops, for household goods and clothing particularly. A feature was the establishment of a number of branch stores by several large city businesses. By the mid-1950s the growth in population was such that increases in both educational and hospital facilities were necessary. The Norfolk North Primary School and the new District High School were both built in 1957, and a new hospital was built in the following year to replace the fifty-year-old Cottage Hospital. The type and number of retailing outlets have changed little in recent years, and hospital facilities too appear to be adequate, although steep population increases in the next few years may alter the situation. Education facilities have been rather more heavily taxed, and as a result the High School is currently being enlarged and the Norfolk North primary school is to have new classrooms added.

By 1965 the outlook for the town was not particularly bright. Job opportunities were declining just as large numbers of young people were ready to enter the workforce, and there seemed no option for them but to commute to the city or leave home. However, developments since then have considerably changed the picture for the better.

DERWENT
RIVER
DERWENT
STREET
FERRY STREET
STREET
MONTAGU
STREET
HILL ST.
ALFRED
CHURCH
STREET
STREET
Arthur
Square
STREET
Church
HIGH
STREET
STREET
STEPHEN
BATHURST
Gaol
STREET
GEORGE
STREET
Barrack
Ground
Parsonage
BURNETT
STREET
Hospital
BLAIR
GREY
STREET
HUMPHREY
0
15 CHAINS
NEW NORFOLK
1833


To Magra
ANM
ANM
FAIRVIEW
To Boyer
To Lawitta
TYNWALD
To Hobart
LACHLAN PARK
PEPPERMINT HILL
LAWITTA
KENSINGTON PARK
To Lachlan
NEW NORFOLK 1967
PRE-1940 CONSTRUCTION
POST-1940 CONSTRUCTION
CHAINS
0
20

CONCLUSION

New Norfolk today functions mainly as an industrial, institutional, and regional centre. This last role it has held from the very beginning. By Macquarie's decree the town was created 'for the District of New Norfolk', and this it has served and by this it has been at least in part maintained for over 150 years. The prosperity of the relationship has been determined by the prosperity of agriculture in the valley; first in wheat and potato growing, then in the establishment of hopfields and orchards, and later, of the small fruits industry as well. Yet the central place function has never been the town's sole reason for being, although it was the chief one for much of last century. In the early days when settlements were sparse and communications limited the town was an important administrative centre, and related to this was the establishment there of the military hospital. By midcentury this had assumed its role as Tasmania's mental institution, and expansions associated with this, in the past and in more recent years, ensured its operation as a dominant town function today.

Increased mechanisation early in the present century increased New Norfolk's accessibility and thus fostered the development in the town of small industries utilising the products of the region. Improved transport and communications also opened the way to the use of Hobart as well as or even rather than New Norfolk as a centre for the Derwent region. Smailes has said 'Towns no longer belong to the countryside as they once did', and this is true of New Norfolk since the introduction and development there of the newsprint industry. The town is still in the countryside, and, largely independent of other urban centres, it may still be called a country town, but its interests and associations are with the town itself.

Growing industrialisation and Hobart competition together are working to reduce the town's role as a regional centre—relative to other town functions, if not yet absolutely. The importance of the mental institution to the town also is declining in relation to industry, although otherwise it is not likely to change very much, independent as it is of the region and of economic interests. The industrial role therefore is dominant and on the increase, yet it should nevertheless be recognised that this is limited. The Town and Country Planning Commission Report of 1957 states—

> 'New Norfolk has certain advantages in industrial location: there is ample water and there are good communications and excellent factory sites . . . However one should be guarded against unfounded optimism: the desire by prospective industrialists to locate their factories as close as possible to large centres is still very powerful . . .'.

Developments of the last ten years notwithstanding, this still holds true. The New Norfolk site happens to suit the peculiarities of the newsprint industry but has little to attract anything else. There is a reserve of female labour, but with the outskirts of Hobart only twelve miles away factories locating in or nearer the metropolitan area could still draw on much of this and also enjoy the advantages of better transport links, with the port and with the main north-south highway, a wider labour shed, and greater proximity to related businesses and industries. Beyond the bounds of ANM expansion, then, New Norfolk's future role appears to be that of an outer suburb of metropolitan Hobart.

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REFERENCES

Statistics of the State of Tasmania, for the years 1888, 1891, 1901, 1911-12, 1922-23, 1932-33, 1947-48, 1954-55, 1961-62.
Census of the Commonwealth of Australia,: 1911, 1921, 1933, 1947, 1954, 1961.
Town and Country Planning Commission: *New Norfolk Planning Scheme*, 1957.
Australian Newsprint Mills Limited, Boyer: Company publication, 1965.
Tasmanian Post Office Directory: 1890-91, 1901, 1911, 1921, 1932-33, 1934-35, 1935-36, 1936-37, 1939-40, 1941, 1947.
Tasmanian Telephone Directory: 1952, 1954, 1957, 1958, 1961, 1965.
Bailliere's *Tasmanian Gazetteer and Road Guide*, 1877.
McPhaill's *Directory of Tasmania*, 1867-1868.
F. B. Maning's *Tasmanian Directory*, 1881-1882.
Melville's *Almanack*, 1831, 1832, 1833, 1834, 1836.
Ross' *Almanack*, 1830, 1831, 1832, 1835, 1837, 1869, 1874.
Wood's *Tasmanian Almanack*, 1850.
'*Hobart Town Gazette*' 24 April 1825.
'*Hobart Town Courier*' 14 April 1832.
'*Tasmanian Mail*' 30 May 1885.
Historical Records of Australia, Series III, Volumes I and V.
Archives of the State Library of Tasmania: Files of the Colonial Secretary's Office (CSO), 1824-1836.
BETHELL, L. S., 1961—*The Valley of the Derwent*, Hobart.
CROKER, C. (ed.), 1838.—Memoirs of Joseph Holt, Volume II, London.
HARTWELL, R. M., 1954.—*The Economic Development of Van Diemen's Land*, 1820-1850, Melbourne.
HOOKEY, M. (Ed.), 1929.—*Bobby Knopwood and his Times*, from Knopwood's diaries of 1804-1808, 1814-1817, Hobart.
LACHLAN MACQUARIE, Governor of New South Wales; *Journals of his Tours in New South Wales and Van Diemen's Land*, 1810-1822, Sydney 1956.
LYCETT, J., 1925.—*Views in Australia, or New South Wales and Van Diemen's Land*.
MCKAY, A. (Ed.), 1962.—*Journals of the Land Commissioners for Van Diemen's Land*, 1826-1838, Hobart.
SCOTT, P., 1964.—'The hierarchy of central places in Tasmania', *Australian Geographer*, March 1964, pp. 134-147.
SMAILES, A. E., 1957.—*The Geography of Towns*, London.
SYME, J., 1848.—*Nine Years in Van Diemen's Land*, Dundee.
TOWNSLEY, W. A., 1955.—'Tasmania and the great economic depression, 1858-1872', *Papers and Proceedings of the Tasmanian Historical Research Association*, Volume 4, No. 1.
VON STIEGLITZ, K. R., 1962.—*A History of New Norfolk and the Derwent Valley*, Hobart.
WALKER, J. B., 1914.—*Early Tasmania*, Hobart.
WEST, J., 1852.—*The History of Tasmania*, Volume I, Launceston.

A RECORD OF THE SILVER SPOT THREPTERIUS MACULOSUS RICHARDSON 1850 FROM TASMANIA

By

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(With one plate)

ABSTRACT

A specimen of the Silver Spot *Threpterius maculosus* is briefly described. This constitutes the first record of this species for Tasmania.

INTRODUCTION

In May 1968 a fish forwarded to the Tasmanian Museum for identification corresponded with Scott's (1962) description of the Silver Spot and recorded by Scott as occurring in South Australia and Western Australia only.

The fish, measuring 325 mm., was captured by a fisherman off North Bruny Island, Tasmania, and was sent to the Museum deep frozen in an excellent state of preservation. A specimen loaned by the South Australian Museum corresponded in all recognisable features with the North Bruny specimen which has now been added to the Tasmanian Museum collections (Reg. No. D948) as the first record for the State.

Measurements:—*Threpterius maculosus*, Reg No. D948—

Total length	325 m.m.
Snout tip to—	
Base of caudal fin	277 m.m.
Dorsal origin	55 m.m.
Ventral origin	93 m.m.
Anal origin	158 m.m.
Posterior edge of dorsal	243 m.m.
Posterior edge of anal	207 m.m.
Posterior edge of operculum	81 m.m.
Eye origin	11 m.m.
Maximum depth of body	98 m.m.
Length of 5th dorsal spine (longest)	35 m.m.
Eye width	18 m.m.
Eye height	19 m.m.
Body weight and sex	not determined

Colour:—Reddish yellow with large irregular dark-brown patches on sides with numerous black spots on the fins.

Fin and Ray Count:—D xiv/19, A iii/8, C 15, V i/5, P 14, L. lat. 61 approximately.

ACKNOWLEDGMENT

I should like to thank Mr C. J. M. Glover of the South Australian Museum for making a specimen of the Silver Spot available to me for comparison.

Reference

Scott, T. D., 1962.—The Marine and Freshwater Fishes of South Australia. W. L. Hawes, Government Printer, Adelaide.

Silver Spot *Threpterius maculosus* Richardson

Papers and Proceedings of the Royal Society of Tasmania, Volume 102—Part II

THE NATURE OF TASMANIAN OIL SHALE

By

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ABSTRACT

Since deposition, the organic matter of most oil shales has been so changed over geological time that little recognisable features remain. Microscopical examination does not provide much help for constitutional analysis and thus one cannot use biological features as a basis for classification. Tasmanite oil shale is a notable exception. The kerogen is so sharply differentiated from the mineral matrix that it can be largely separated by mechanical means.

Tasmanite kerogen, when isolated, appears as flattened discs, which, by various sectioning processes, can be shown to have been nearly spherical in shape before compaction. There has been a great deal of argument as to the exact nature of these dissemenules. The century-old suggestion, originally rejected, that they are algal in origin has now been generally accepted and it may be taken that *Tasmanites*, as it occurs in oil shale, represents the cyst stage of a peculiar alga belonging, most likely, to the Chlorophyceae. The exact relationship within the family is still uncertain.

Because of its discrete and peculiar structure, it might be assumed that the organic matter of tasmanite has a chemistry different from other algal shales. This is true only in so far as the soluble resin-like material is concerned, the pyrolysate possesses a normal hydrocarbon chemistry, although the non-hydrocarbon constituents are somewhat more than usual. Infrared and other physical methods of analysis support this hypothesis.

INTRODUCTION

Thirty years ago, the plenary session of the first Conference on Oil Shale and Cannel Coal adopted a resolution that a standard nomenclature for oil shale was most desirable and that a suitable classification should be secured: no such scheme has ever been adopted. One of the difficulties of any system based on the nature of kerogen itself has been the virtual absence of recognisable features in the organic matter of the rock, the biological progenitor having been so macerated and metamorphosed that little of the original structure remains. One notable exception is the oil shale called tasmanite, which has characteristics so different from normal that, for over a century, it was believed to be utterly dissimilar from all others. In their early classification, Down and Himus (1940) regarded tasmanite as unique and placed it in a separate category.

The purpose of this paper is to record the nature and thermal behaviour of this peculiar oil shale, large deposits of which were, until recently, regarded as endemic to Tasmania. However, in 1966, Tourtelot, Tailleur and Donnell (1966) described a particularly rich, although not so distinctive, deposit which has been found in Alaska. This paper deals exclusively with the Tasmanian deposit. The chemistry of the Alaskan material will be the subject of a later contribution.

It is outside the scope of the paper to discuss the geological features of tasmanite as these have been amply covered elsewhere [see Banks (1962), also Reid (1924)]. For completeness, however, a summary is given.

OCCURRENCE AND NATURE

Tasmanite occurs as a single dichotomous seam, or two closely associated seams, about 5 feet thick in the Lower Permian in a relatively restricted area in north western Tasmania, fairly close to the coast. It would appear that the boundary of the deposit followed roughly the coast of the Permian sea and was associated with shallow waters of the coastal islands. Above and below tasmanite are mudstones associated with pebbly conglomerates. Insignificant patches of tasmanite have also been observed at other isolated places in northern Tasmania as well as on the mainland of Australia. There is no recorded occurrence in southern Tasmania.

The mineral matrix consists largely of fine siliceous mudstone, silica particles and clay, together with small amounts of carbonates and sulphides. The total mineral matter varies between 50% and 90% of the entire rock, with a corresponding specific gravity range of 1.2—1.6. Although the composition of the ash does not vary very much with the richness of the seam, adventitious inclusions of quartz, grit and pyrite are to be found throughout the deposit. A range of representative analyses (various authorities) of the ignited mineral matter is shown (% w/w) in Table 1.

Table 1

Analysis of Tasmanite Ash

Constituent	Range %
Silica	70 — 77
Alumina	11 — 16
Fe_2O_3	5 — 7
CaO	0.4 — 4
MgO	0.7 — 3
SO_3	0.4 — 2
K_2O	2 — 3
Na_2O	0.5 — 2

The rock itslf is grey-brown in colour, soft, fissile and combustible. When examined closely, many

samples of tasmanite have a minute speckled appearance produced by innumerable orange spots just visible to the naked eye. These discrete particles are tasmanite 'kerogen', or perhaps more correctly, the spores, *Tasmanites punctatus* (Newton), are composed of kerogen.

The organic matter of tasmanite is different from any other rock type and consists nearly entirely of numberless yellowish clearly differentiated small discs embedded in the mineral matrix. The discrete particles, when viewed under the microscope perpendicular to the bedding plane, appear, when whole, as translucent disc-shaped bodies, roughly ½ mm in diameter with a creased and sculptured surface. In transverse section, innumerable distorted overlapping flattened 'sausages' are observed and it is not unreasonable to assume that the undistorted entities were nearly spherical in shape. They have become flattened and creased under geological pressure. The nature of the surface sculpturing and the spore morphology have been discussed by Singh (1931) and Wall (1962). Opinion on the exact nature of the 'spore cases' has varied widely and, in this paper, the term 'spore' will be used to designate the particulate bodies which, in aggregate, make up most of the kerogen of tasmanite. It is not meant to infer that they are true spores in the botanical sense, a more suitable term might be dissemenules.

Descriptions of tasmanite date from 1857 when the first record of the rock appeared in the 'Papers and Proceedings of the Royal Society of Van Diemen's Land'. In the ensuing decade, several references to this 'combustible schist' or 'white coal' were made in the scientific literature until, in 1864, the name 'tasmanite' was given by Church (1864). Somewhat later, Newton (1875) isolated the spore bodies mentioned above and applied the generic name '*Tasmanites*' in deference to their origin and specifically '*punctatus*' because of their punctation or surface markings.

Initially the 'spores' were claimed by Ralph (1865) to be algal in origin, but Newton (1875) rejected this idea and suggested that they were 'allied to Lycopdiaceous macrospores'. For a long time, these disc-like microfossils were regarded, not without suspicion, as belonging to a plant possibly allied to the Lepidodendrales and Equisetales. However, in 1941, Kräusel (1941) showed that the tasmanite discs were indeed fossil leiospheres derived from an alga probably belonging to the Chlorophyceae and this has remained the consensus; the genus retaining the name '*Tasmanites*'. Somewhat later, Wall (1962) reaffirmed the identity of *Tasmanites* and showed its close affinity to the extant spherical green alga *Pachysphaera pelagica* (Ostenfeld 1899), both of which he placed in the Leiosphaeridae. The paleobotany of both *Tasmanites* and *Leiosphaerida* have been discussed by Eisenack (1958). It would appear that the relationship between *Pachysphaera* and *Tasmanites* is closely parallelled by variants of *Botryococcus braunii* which is sometimes found in vast quantities in the Coorong in South Australia and in certain lakes in Siberia. In the case of *Botryococcus*, the Permian alga responsible for the torbanites of Scotland and Australia so closely resembles its present day counterpart that palaeobotanists cannot justify a separate genus and have decided to retain the same name for both. Wall's contention that '*Pachysphaera* is regarded as a living representative of the fossil genus *Tasmanites*' would apply equally well to *Botryococcus*, which contributes both to the extant Coorongite and to fossil fuel torbanite.

The detailed paleobotanical features and taxonomy of *Tasmanites* have been the subject of considerable argument in the scientific literature. It is outside the writer's province to discuss the various arguments and reference should be made to 'Genera of Paleozoic Fossil Spores (Tasmanites)' in Schoff, Wilson & Bentall's paper (1944) and to the section 'Dissemenules of Unknown relationship—Tasmanites' in Winslow's recent survey (1962).

ISOLATION OF TASMANITE KEROGEN

The beneficiation of the organic matter (kerogen) in oil shale by protracted leaching has received extensive study over a long period [see Carlson (1937) and McKee & Goodwin (1923)]. Usually chemical dissolution with removal of the mineral matter is either weak and ineffectual or so drastic as to attack the kerogen itself. In the case of tasmanite, however, an initial efficient separation may be achieved by crushing and weak acid leaching followed by systematic screening. As the individual spores are large and of a relatively narrow size range, conventional sieves may be used, Singh (1931) gives the extremes as 200–533μ with a mean diameter of 366μ.

It is interesting to note that the screen fractions showed the systematic change in properties given in Table 2. The smaller mesh size consisted of broken spores, pieces of cuticle, fine silica and clay, whereas the +30 mesh consisted essentially of aggregates and adventitious matter.

TABLE 2

Properties of Tasmanite vs. Particle Size

Screen Size	Ash % w/w	Colour of Ash
+30	27	red
—30, +50	41	pink
—50, +70	67	pale pink
—70	88	pinkish grey

If the gangue be removed as 'sink' in an aqueous solution of specific gravity 1.2 and the 'float' be screened on a 30, 40, 50, 70, 100 mesh screen system, virtually pure spores may be collected within the —40, +50 mesh size.

CONSTITUTION OF TASMANITE KEROGEN

The organic matter of tasmanite may be divided, from the viewpoint of morphology, into—

(1) Entire or nearly entire spores which make up about three-quarters of the kerogen.
(2) Residual organic matter which, under the microscope, appears as spore fragments, cuticle, vegetal dust and other detritus.

If the spores be removed, the residual organic matter is still oil yielding, although to a lesser degree (about 14 gal/ton), and it is uncertain how much of the non-spore material is made up by contributions from vascular plant remains.

TABLE 3

Composition of Purified Tasmanite Kerogen
(% w/w)

	Range of Spore Material	Non-Spore Material	Purified Spore Material	Pure Entire Spores
Carbon	76.9 — 78.8	66.1	78.50	78.10
Hydrogen	9.8 — 10.4	10.2	10.35	10.21
Nitrogen	0.59 — 0.64	1.3	0.64	0.61
Sulphur	4.66 — 5.12	2.00	4.70	5.14
Oxygen (diff.)	5.81 — 9.67	20.4	5.81	5.94

The examination described below was carried out on a sample of 'spore case' concentrate which had been prepared, many years previously, by flotation concentration in a ferric chloride solution. The sample, which received no chemical treatment, is referred to hereafter as 'the concentrate'.

A second quantity of the screened spore concentrate was treated according to the eleven stage purification described by Zetzsche, Vicari and Scharer (1931). Unfortunately, this prolonged treatment ruptured many spores, but on re-screening a quantity of entire, chemically pure spores was recovered. Zetzsche, et al., asserted that the purified organic matter was nitrogen and sulphur free and had an elemental analysis corresponding to C = 72.5%, H = 9.2%, O = 18.2%, but one must regard these data of questionable value. Later work by Kurth (1934), cast grave doubts on the above analysis and he demonstrated that normal spores had a remarkably uniform composition which is shown in Column IV, Table 3 (even when purified according to Zetzsche, et al.). However, Kurth found that the non-spore organic material was variable in composition and a representative analysis is given in Column III of Table 3.

Once again one must emphasize that it is imprudent to regard kerogen as a specific substance and, as Cane has pointed out elsewhere (1967), it seems extremely improbable that any kerogen has a chemical constitution in the classical sense. Nevertheless, within the accepted definition, these spores, together with much broken material, etc., are indeed the kerogen of tasmanite.

Although both the macroscopic and microscopic features of tasmanite might lead one to suspect a chemistry somewhat dissimilar from other shales, this has not been shown to be the case, except for the more important role of sulphur and the nature of the 'solubles'. Superficial examination of elemental analyses would suggest a 'rank' lower than other algal shales, but careful plotting of published data on a Ralston diagram shows no significant trend and, on a sulphur and nitrogen-free basis, the elemental composition is not abnormal. If, however, one's consideration includes nitrogen and sulphur, it can be seen that the latter element is notably high—organic sulphur exceeds 5% in some samples on a 'dry ash-free' basis. The only other organic rock surpassing this figure is Kimmeridge oil shale [Himus (1951)] which, in nearly every aspect, is exceptional.

Tasmanite kerogen which has been concentrated by the flotation/screening technique discussed above is a brown free-flowing powder of specific gravity about 1.09. The ash of the first stage concentrate (flotation/screening) was 24.3%, but after the prolonged chemical purification of Zetzsche, et al., this was reduced to 1.1%. The elemental analysis (d.a.f. basis) is shown in Table 3. The concentrate oil yield was 141 gal/ton (U.S.) from which the calculated yield of pure spore material was 186 gal/ton. The oil yield of the spores, purified by the Zetzsche method, was 189 gal/ton (modified Gray-King Assay).

Infra-red examination of the purified de-ashed spores showed absorption maxima corresponding to C-H stretch, C-H bend, carbonyl (ester) and $(CH_2)_n$ rock frequencies characteristic of most kerogens. The benzene-methanol extract spectrum was much the same, except for a strong absorption at 680 cm^{-1}, to which a polysubstituted aromatic structure is tentatively assigned. There were no major abnormalities in the spectra of either the kerogen or its pyrolysate except that the latter showed a somewhat more substituted aromatic nature in the 740-820 cm^{-1} region, than other shale oils with which the writer has had experience.

THERMAL BEHAVIOUR

On heating at a temperature increase of 100° C per hour, the concentrate behaved in a manner similar to other algal shales, although thermal instability occurred at a lower temperature. Noticeable decomposition commenced at 255-270° with evolution of water contaminated with colloidal sulphur and carbon dioxide and, at a somewhat higher temperature, the production of a dank smelling, honey-like viscid material from which crystals deposited on cooling. This early product, which amounted to 3.2% of the concentrate, was unlike true tasmanite oil and it is assumed that it represents portions of the resinous soluble matter mentioned below. It is interesting to note that the concentrate purified by Zetzsche's method did not show this varnish-like distillate nor the incipient decomposition at 270°C.

Evolution of tasmanite oil, accompanied by the copious production of hydrogen sulphide, started at about 340°, reached a maximum at about 430° and was virtually complete at 480°C. Hydrogen sulphide accounts for nearly half the total sulphur. There was some indication, and this has been noted by previous workers [see Kurth (1934)], that the nature of the initial pyrolysis is dissimilar to that occurring in excess of 340°C, at which temperature oil production starts in earnest.

Although no serious attempt was made to measure the energetics of the pyrolysis, calculation of the kinetics of the oil-forming reaction showed a rate constant of 0.21×10^{-4} sec $^{-1}$ at 350°C, a result strictly comparable with published figures on other shales. The available data did not permit the calculation of activation energies.

When the de-ashed spores were heated to about 350°, there was complete structural collapse and the retort charge was transformed into a bubbling mass of bitumen-like material. This, of course, is the tarry intermediate, characteristic of the penultimate stage of kerogen pyrolysis, which has been previously discussed by Cane (1951). Apparently there is sufficient mineral matter in the case of the concentrate to maintain a degree of solidarity and a coherent mass of coke was obtained. The mineral skeleton is lacking in the purified kerogen.

TASMANITE OIL

Table 4 gives the general properties of tasmanite oil which has been produced by gentle pyrolysis of the concentrate, the temperature being maintained below 450° at all times [taken from Cane (1940)].

TABLE 4

Properties of Tasmanite Oil

Specific Gravity @ 15°C	0.854
Refractive Index @ 15°C	1.4684
Tar Acids %	4.5
Tar Bases %	3.2
Sulphur %	2.22
Nitrogen %	0.34
Saturates %	43.9

The oil is a thin brown liquid with a remarkably clinging odour, thought to be connected with the nitrogen bodies rather than sulphur compounds. It is low in wax but high in sulphur, the amount of which, with respect to distillation temperature, goes through a maximum and then decreases. The sulphur bodies are alkyl and aryl thiols, thiophene and more complex substances. As with all materials of this nature, it is difficult to state with certainty how much sulphur in the oil has been formed during pyrolysis from inorganic sulphur and the organic matter, but oils exceeding 2.7% S have been produced from the upper portions of the seam.

The nitrogen compounds (tar bases) are largely alkyl pyridines and quinolines, but another type of nitrogen compound appears present which could possibly be somewhat alkaloidal in structure. This contention is supported by a pronounced physiological reaction when one is working with the isolated bases. This bio-active material is being examined by another group in this University.

Solubles

The nature of the material extracted by a benzene/methanol mixture is different from that of all other shales so far examined. The extract was a brown resinous varnish-like material (4.1% w/w on the concentrate) unlike the normal waxy or bitumenous extract. An infra-red spectrum showed considerably more aromatic characteristics than usual and it is believed that the extract may consist substantially of portion of the resistant coat discussed by Wall (1962). Possibly the extract may, in its present form, be related to abietic acid as early research gave strong indications of retene structures in the dehydrogenated extract. Further work on the spore extract is being done by the Geophysical Laboratory of the Carnegie Institution of Washington.

REFERENCES

BANKS, M. R., 1962.—Permian in The Geology of Tasmania (Chp. 5). *J. Geol. Soc. Aust.* 9 (2), 189-215.

CANE, R. F., 1940.—Studies in Tasmanian Shale Oil. *Pap. Proc. Roy. Soc. Tas.* 74, 23-32.

———, 1951.—The Mechanism of the Pyrolysis of Torbanite. *Oil Shale & Cannel Coal* Vol. II, 592-604. Institute of Petroleum, London.

———, 1967.—The Constitution & Synthesis of Oil Shale. *Proc. 7th World Petm. Congress (Mexico)*, Vol. III, 681-689. Elsevier, London.

CARLSON, A J., 1937.—Inorganic Environment in Kerogen Transformation. *Univ. Calif. Publ. Engng.* 3, (6), 259-342.

CHURCH, A. H., 1864.—On Tasmanite, a new mineral of organic origin. *Phil. Mag.* 28, 465-470.

DOWN, A. L. and HIMUS, G. W., 1940.—The Classification of Oil Shales and Cannel Coals. *Jour. Inst. Pet.* 26, 329-335.

EISENACK, A., 1958.—Tasmanites and Leiosphaerida n.g. Gattungen der Hystrichosphaerida. *Paleontographia* 110, 1-19.

HIMUS, G. W., 1951.—The Composition of Kerogen Rocks & the Chemical Constitution of Kerogen. *Oil Shale & Cannel Coal* Vol. II, 112-133. Institute of Petroleum, London.

KRAUSEL, R., 1941.—Die Sporokarpien Dawsons, eine neue Thallophyten Klasse der Devons. *Palaeontographia* 86, 113-135.

KURTH, E. E., 1934.—The Oil Shales of Tasmania & N.S.W., D.Sc. Thesis (unpublished) 389 pp. University of Tasmania, Hobart.

MCKEE, R. H. and GOODWIN, R. T., 1923.—Organic Matter in Oil Shales. *Qtly. Colo. School of Mines* 18, (1), 29-51.

NEWTON, E. T., 1875.—On Tasmanite and Australian White Coal. *Geol. Mag.* 12, 337-343.

RALPH, T. S., 1865.—The Microscopical Characteristics presented by a Mineral (Dysodil) from Tasmania. *Trans. Roy. Soc. Vic.* 6, 7,

REID, A. McI., 1924.—The Oil Shale Resources of Tasmania. *Mineral Resources No.* 8, Vols. I & II. p. 14 *et seq.*, Geological Survey, Dept. of Mines, Tasmania.

SCHOPF, J. M., WILSON, L. R., and BENTALL, R., 1944.—An Annotated Synopsis of Paleozoic Fossil Spores. *Report of Investigations No.* 91, *State Geological Survey*, p. 11 *et. seq.*, Illinois.

SINGH, T. C., 1931.—Notes on the Fossil Spores in an Oil Shale from Tasmania. *Pap. Proc. Roy. Soc. Tas.*, 66, 32-36.

TOURTELOT, H A. and TAILLEUR, I. L., 1966.—Oil Yield & Chemical Composition of Shale from Northern Alaska. *U.S. Geol. Survey*, open file Report, 1965, 17.

WALL, D., 1962.—Evidence from recent Plankton regarding the biological Affinities of Tasmanites (Newton 1875) and Leiosphaeridia (Eisenack 1958). *Geol. Mag.* 99, 353-362.

WINSLOW, M. R., 1962.—Plant Spores & Other Microfossils from Upper Devonion & Lower Mississippian Rocks of Ohio. *Geological Survey, Professional Paper No.* 364, p. 77. U.S. Geological Survey, Washington.

ZETZSCHE, F., VICARI, H., and SCHARER, G., 1931.—Untersuchungen über die Membran der Sporen und Pollen, IV. Part 3, *Helv. Chim. Acta* 14, 67-78.

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NEW SPECIES OF TOXOPIDAE AND ARCHAEIDAE (ARANEIDA)

By

V. V. Hickman

(With thirty figures)

ABSTRACT

A new species, *Laestrygones setosus*, is described and placed in the family Toxopidae. The female has double-pointed fangs on the chelicerae. The same feature is also recorded for the New Zealand spider, *Laestrygones albiceris* Urquhart. Four new species of *Pararchaea* Forster in the family Archaeidae are described. They are *P. corticola*, *P. saxicola*, *P. ornata* and *P. bryophila*. Remarks on the genus *Pararchaea* are added.

Family TOXOPIDAE

Genus **LAESTRYGONES** Urquhart 1894

Laestrygones setosus sp.n.

(Figs 1-9)

Male (holotype).—Measurements in millimetres:—

Body length	1.77
Length of carapace	0.80
Width of carapace	0.68
Height of carapace	0.51
Length of abdomen	0.91
Width of abdomen	0.63

Leg	*Femur*	*Patella*	*Tibia*	*Meta-tarsus*	*Tarsus*	Total
1	0.57	0.26	0.51	0.45	0.34	2.13
2	0.64	0.27	0.52	0.49	0.40	2.32
3	0.55	0.26	0.48	0.49	0.35	2.13
4	0.68	0.23	0.52	0.64	0.38	2.45
Palp	0.18	0.11	0.11	—	0.38	0.78

Colour.—Carapace yellowish brown with a dark brown longitudinal area on each side. Between the dark brown area and the lateral margin are some irregular dark marks. On the clypeus are two dark marks below the eyes. The chelicerae, maxillae, labium and sternum are yellowish brown. Each chelicera has a black mark in front and the sternum is dark round the margin. The legs are yellowish brown with dark spots on femora, tibiae and metatarsi. The abdomen is yellowish brown with a longitudinal dark mark on each side of the dorsal surface. Laterally the abdomen is marked with a dark brown band speckled with yellow, the two bands uniting above the spinnerets. The ventral surface and spinnerets are yellowish.

Carapace.—High, ovate, widest between the third coxae and becoming narrower towards the front, which is somewhat truncate (fig. 1). Posteriorly it slopes steeply to the hind margin. A thoracic fovea is indistinct. The surface is provided with a number of long erect barbed bristles distributed in a regular manner.

Eyes.—Viewed from above the eight eyes appear in two strongly recurved rows (fig. 2). They may be regarded as forming three rows, the first being composed of AME, the second of ALE and PME, and the third of PLE. The eye ratio AME : ALE : PME : PLE = 5 : 5 : 6 : 6. AME and ALE are mounted on black rings. PME and PLE are slightly yellowish brown and are mounted on yellowish brown rings. The ocular region occupies the full width of the carapace. AME are separated from each other by 4/5 and from ALE by 6/5 of their diameter. PME are separated from each other by 11/6 and from PLE by 5/6 of their diameter. The median ocular quadrangle is wider behind than in front in ratio 11 : 7. Its length is greater than its anterior width in ratio 17 : 14. The height of the clypeus is 8/5 the diameter of AME.

Chelicerae.—Erect and conical. Lateral condyles absent. On the front or prolateral surface there are a few barbed hairs and, near the base, a large stout bristle. On the retrolateral surface are a few short hairs and three long slender barbed bristles. On each side near the base of the fang is a long sinuous barbed hair. The furrow is oblique. There is a light scopula and two teeth on the promargin. Three teeth are present on the retromargin, the basal tooth being small (fig. 3). The fang is moderately long and curved.

Maxillae.—Somewhat rectangular, longer than wide, slightly convergent, with a scopula on the apical half of the inner margin and a well developed serrula on the anterior margin. Surface provided with a few coarse hairs.

Labium.—Wider than long in ratio 10 : 7, rounded at the sides, truncate in front, slightly more than half the length of the maxillae and provided with a few coarse hairs.

Sternum.—Shield-shape, longer than wide in ratio 20 : 19, and ending in a point between the fourth coxae. The surface is clothed with a few coarse hairs, which are inclined forward.

Legs.—Length order 4.2.1.3. Laterigrade, clothed with barbed hairs and armed with long erect bristle-like spines. Two trichobothria and a small drum are present on each tarsus. The more distal trichobothium is the longer and the drum is close beyond its base. The first, second and fourth metatarsi each have two trichobothria and the third three. The first, second and fourth tibiae each have four distributed two on each side. The third tibiae have five, three on one side and two on the other. Three tarsal claws are present. The upper claws are similar with 8 or 9 teeth on the basal half. The lower claw is bare. Trochanters lack a notch.

Spines.—First leg. Femur dorsal 0-1-1, prolateral 0-0-1, retrolateral 0, ventral 1-1-1-2-2. Patella dorsal 1-1. Tibia dorsal 1-1, prolateral 1-1, retrolateral 1-1, ventral 2-2-0. Metatarsus dorsal 0-1-1, prolateral 0-1-1, retrolateral 0-1-1, ventral 2-2-2. Tarsus 0. *Second leg.* Same as first. *Third leg.* Femur dorsal 0-1-1, prolateral 0-0-1, retrolateral 0, ventral 1-1-2-2. Patella dorsal 1-1. Tibia dorsal 1-1, prolateral 1-1, retrolateral 1-1, ventral 1-2-0. Metatarsus dorsal 1-1, prolateral 1-1, retrolateral 1-1, ventral 2-1. Tarsus 0. *Fourth leg.* Femur dorsal 0-1-1, prolateral 0, retrolateral 0-0-1, ventral 0-2-2. Patella dorsal 1-1. Tibia dorsal 1-1, prolateral 1-1, retrolateral 1-1, ventral 1-1-2. Metatarsus dorsal 1-1, prolateral 1-1, retrolateral 1-1, ventral 2-2-1. Tarsus 0.

Palpi.—Almost equal in length to the carapace. Clothed with barbed hairs and spines. The latter are distributed as follows:—Femur dorsal 1-1, elsewhere 0. Patella dorsal 1-1. Tibia dorsal 1-1, prolateral 1, retrolateral 0, ventral 0. Tarsus dorsal 1-1-1, prolateral 1-1, retrolateral 1-0, ventral 1 near apex. The apical half of the dorsal surface of the tarsus has a dense clothing of short barbed hairs. The tibia has two trichobothria and three apical apophyses (figs 4 and 5). The first apophysis is short, dentiform and on the dorsal side. The second and third are close together on the retrolateral side. The second apophysis ends in two sharp points. The third is below the second apophysis. It is elongate and ends in a blunt point, which has three short setae on one side. The cymbium is spoon-shaped. The median division of the bulb has a short conical apophysis and a number of short spinules. The embolus is short.

Abdomen.—Broadly ovate. Lightly clothed with recumbent barbed hairs, which on the dorsal side, are intermingled with long erect bristles distributed in a regular manner (fig. 1). The spinnerets are situated ventrally a little in front of the posterior end of the abdomen. They are sub-conical in shape. The anterior pair are the largest and have a very short apical segment. A short colulus bearing about 15 long hairs is present. The tracheal spiracle is immediately in front of the colulus. Serial sections of a paratype specimen show that the spiracle leads into two wide trunks, which pass forward and, near the epigastric furrow, divide into a large number of small tracheal tubes. Eighty or more of these tubes pass through the petiolus and enter the cephalothorax and its appendages. On the ventral side of the abdomen immediately in front of the tracheal spiracle is a transverse group of short barbed spinules (figs 6 & 7). The group is a little wider than the spinnerets and the spinules are arranged in about three irregular rows.

Female (allotype).—Measurements in millimetres:—

Body length	2.11
Length of carapace	0.86
Width of carapace	0.74
Height of carapace	0.57
Length of abdomen	1.25
Width of abdomen	0.91

Leg	*Femur*	*Patella*	*Tibia*	*Metatarsus*	*Tarsus*	TOTAL
1	0.65	0.30	0.52	0.41	0.34	2.22
2	0.68	0.31	0.44	0.44	0.41	2.28
3	0.67	0.27	0.44	0.42	0.37	2.17
4	0.74	0.27	0.49	0.61	0.41	2.52
Palp	0.28	0.15	0.21	....	0.30	0.94

The female resembles the male in general appearance but is slightly larger and lighter in colour. Only the following features need be described.

Chelicerae.—The fangs are remarkable and differ from those of the male in being double-pointed (fig. 8). The two points are side by side, but the one on the prolateral or front side is the shorter. In other respects the chelicerae resemble those of the male.

Legs.—Length order 4.2.1.3. Clothed with hairs and spines as in the male. There are two trichobothria and a small drum on each tarsus. On the first metatarsus there are also two trichobothria but on each of the other metatarsi there are three. Each tibia has five, two being on one side and three on the other.

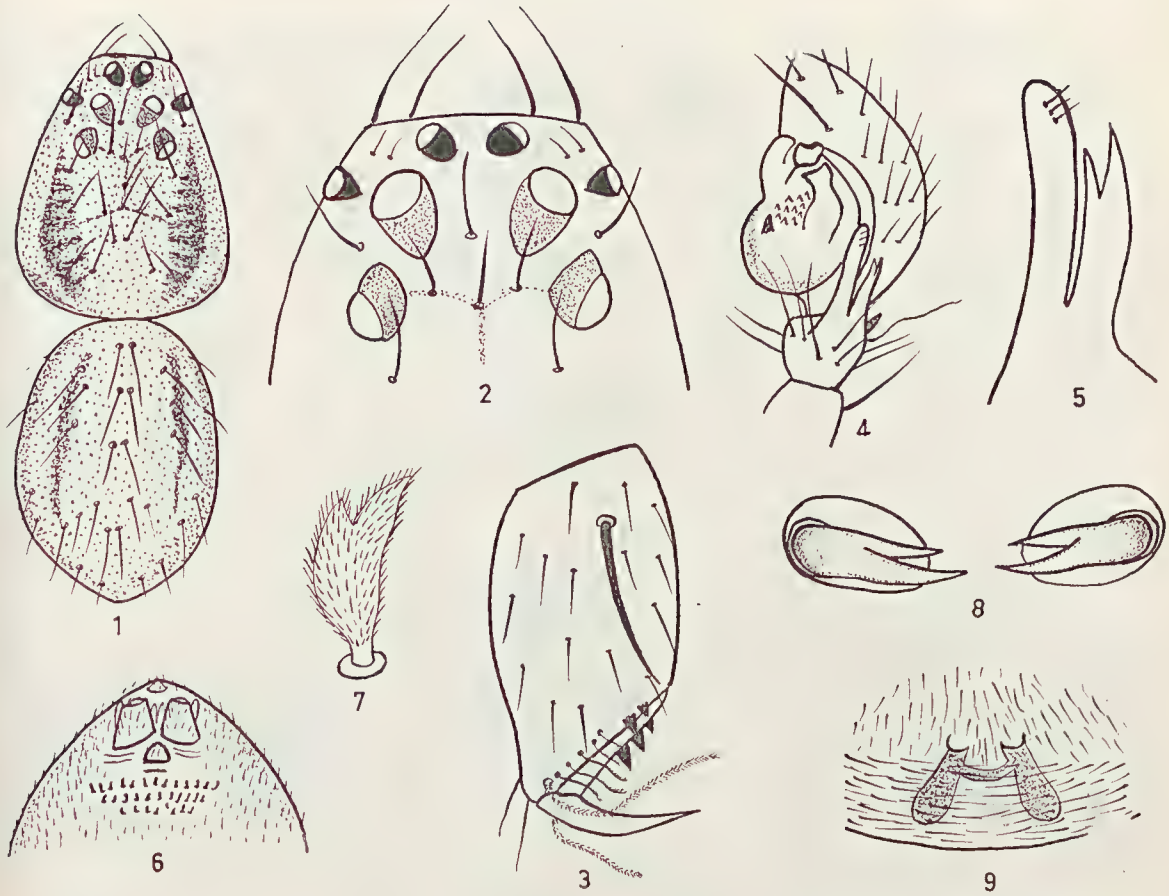
Palpi.—Slightly longer than carapace. The spines are distributed as follows:—Femur dorsal 0-1-1, prolateral 0-0-1, elsewhere 0. Patella dorsal 1-1. Tibia dorsal 1-1, prolateral 1-1, retrolateral 1-1, ventral 0. Tarsus dorsal 1-1, prolateral 1-1, retrolateral 1-1, ventral 2-2-2. There are three trichobothria on the tibia and none on the tarsus. The tarsal claw is almost straight and without teeth.

Abdomen.—Broadly ovate. Clothed with barbed hairs and long erect bristles as in the male. The group of spinules and colulus are also as described in the male. The epigynum consists of two small apertures, each bounded behind by a sclerotized half ring. The apertures lead into a pair of pyriform spermathecae, which are partly visible through the integument. Between the two apertures and the epigastric furrow the hairs are directed transversely (fig. 9).

Occurrence.—The holotype male and allotype female were found in grass tussocks at the Domain, Hobart, Tasmania, 26 March 1968. Paratype male and female were also taken.

Affinities.—Laestrygones setosus is closely related to the New Zealand spider *L. albiceris* Urquhart, which is the only other species recorded in the genus. (The specific name spelt '*albiceres*' by Urquhart and others has been corrected to '*albiceris*' by Bonnet (1957).) Forster has described the male and discussed the synonymy of the New Zealand spider in a series of papers (1955(a), 1964(a), 1964(b)). *L. setosus* is only about half the size of *L. albiceris* and may be distinguished by the form of the male palp and female epigynum.

Examination of a female specimen of *L. albiceris* from Mangarei, New Zealand, and sent to me by Mr C. L. Wilton, shows that it likewise has double-pointed fangs on the chelicerae. The feature appears to have been overlooked by Urquhart and other authorities. It is probably of generic importance.



Laestrygones setosus sp.n.

FIG. 1.—Dorsal view of body of male
FIG. 2.—Eyes
FIG. 3.—Prolateral view of male chelicera
FIG. 4.—Retrolateral view of male palp
FIG. 5.—Tibial apophysis of palp
FIG. 6.—Group of spines in front of spinnerets
FIG. 7.—A single spine from group in front of spinnerets
FIG. 8.—Ventral view of partly extended fangs of female
FIG. 9.—Epigynum

Forster (1964(b)) has placed *Laestrygones* in the family Toxopidae. Lehtinen (1967), however, has transferred it to his group Zodariides, with which it seems to have little affinity.

Family ARCHAEIDAE

Genus **PARARCHAEA** Forster 1955

Key to females of species of *Pararchaea* Forster

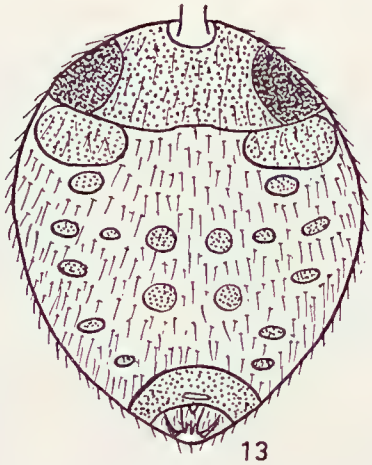
1. Tibia of first leg longer than tarsus 2
   Tibia of first leg equal to or shorter than tarsus 3
2. A row of five sclerites on each side below abdomen .... *P. corticola* sp. n.
   No sclerites on each side below abdomen *P. saxicola* sp. n.
3. Abdomen yellow with reddish or brown markings 4
   Abdomen uniform pale yellow or cream 5
4. Abdomen with dark median stripe and chevrons above .... *P. ornata* sp. n.
   Abdomen orange yellow with reddish markings *P. rubra* (Forster)
5. Femur of first leg with a row of peg-like spines 6
   Femur of first leg without such spines *P. bryophila* sp. n.
6. Femur of second leg with stridulating ridges *P. binnaburra* Forster
   Femur of second leg without such ridges *P. alba* Forster

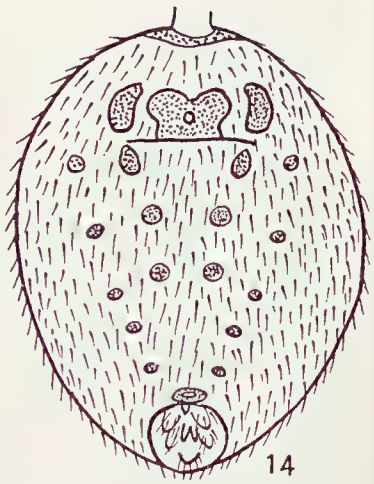
Pararchaea corticola sp. n.

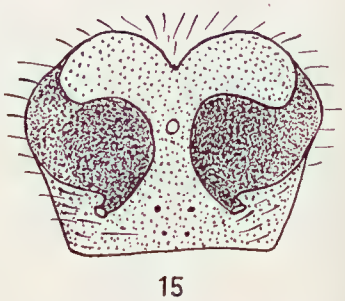
(Figs 10-15)

Male (holotype).—Measurements in millimetres:—

Body length	2.28
Length of carapace	0.86
Width of carapace	0.69
Height of carapace	0.66
Length of abdomen	1.43
Width of abdomen	1.20
Length of chelicerae	0.55







Pararchaea corticola sp.n.

Fig. 10.—Prolateral view of male chelicera
Fig. 11.—Retrolateral view of male palp
Fig. 12.—Dorsal view of abdomen of male
Fig. 13.—Ventral view of abdomen of male
Fig. 14.—Ventral view of abdomen of female
Fig. 15.—Epigynum

Leg	*Femur*	*Patella*	*Tibia*	*Metatarsus*	*Tarsus*	Total
1	0.64	0.25	0.45	0.34	0.38	2.06
2	0.61	0.25	0.41	0.33	0.37	1.97
3	0.55	0.19	0.37	0.31	0.32	1.74
4	0.71	0.26	0.56	0.41	0.36	2.30
Palp	0.25	0.11	0.29	—	0.41	1.06

Colour.—Carapace, chelicerae, palpi and sternum brown. Legs brown except coxae, trochanters and patellae, which are yellowish. Abdomen yellowish except the sclerites, which are brown.

Carapace.—High and sloping forward. Posterior surface slightly indented and descending very steeply to the hind margin. Cephalic part somewhat rounded above and lightly clothed with barbed hairs that slope forward. Thoracic part with radial grooves faintly marked and fovea indistinct.

Eyes.—The eight eyes are arranged in two transverse rows. When viewed from above the front row appears recurved and the hind row straight. All the eyes are surrounded by black rims. The AME are dark, the other eyes pearly white. The eye ratio AME : ALE : PME : PLE = 6 : 6 : 5 : 6. AME are separated from each other by 5/6 and from ALE by 1/2 of their diameter. The lateral eyes are contiguous. PME are separated from each other by twice their diameter and from PLE by 7/5 of their diameter. The median ocular quadrangle is wider behind than in front in ratio 19 : 16. Its length is shorter than its posterior width in ratio 15 : 19. The height of the clypeus is equal to 4/3 the diameter of AME.

Chelicerae.—Long, moderately stout, constricted near the base and devoid of lateral condyles. The front or prolateral surface is provided with stridu-

lating ridges. The fang is short and well curved. The furrow is shallow and indistinct. On the promargin is a row of nine rod-like teeth placed close to one another. Slightly in front of the three basal teeth is a second row of three somewhat larger teeth. When the fang is closed it lies behind the two rows instead of between them. Hence both rows are prolateral in position and there are no teeth on the retromargin (fig. 10).

Maxillae.—Strongly converging over front of labium. Provided with an apical scopula and well developed serrula.

Labium.—Wider than long, immobile, rounded in front and provided with a few long barbed hairs.

Sternum.—Shield-shaped, convex, longer than wide in ratio 15 : 14 and ending in a truncated point between the fourth coxae, which are separated by slightly more than twice their diameter. The surface is marked with a reticulate or polygonal pattern and clothed with a few barbed hairs. The margin is excavated opposite the bases of the coxae.

Legs.—Length order 4.1.2.3. Clothed with barbed hairs, the barbs being more strongly developed on the tarsal hairs than elsewhere. Spines are absent except for an oblique row of five short peg-like spines on the retrodorsal surface near the base of the femora of the first pair of legs. A single trichobothrium is present on each metatarsus; two on the tibiae of the first, second and third legs and four on the tibiae of the fourth legs. Each tarsus has a drum but no trichobothria. Three tarsal claws are present, the upper claws being similar with two or three teeth. The lower claw is strongly bent and has one tooth. Accessory claws are also present. The trochanters are without a notch.

Palpi.—Rather short. There are no apophyses on femur, patella or tibia. A single trichobothrium is present on the tibia. The tarsus is spoon-shaped with the base produced into a large hook-like apophysis on the retrolateral side (fig 11). The embolus projects from the bulb in a sharp point near the apex of the tarsus. The palpi are lightly clothed with a few barbed hairs.

Abdomen.—Ovoid. A small scute is present on the anterior two-thirds of the dorsal surface (fig 12). Between the hind margin of the scute and the spinnerets there are four transverse rows of small sclerites. In the front of the abdomen the petiolus is surrounded by a large sclerotized plate, which extends upward almost to the front of the dorsal scute. Behind the petiolus the plate covers the epigastrium (fig 13). Near the middle of the ventral surface are four circular sclerites or muscle spots forming a quadrangle. On each side immediately behind the epigastric furrow is a large oval sclerite followed by a longitudinal row of five smaller sclerites extending towards the spinnerets. Immediately in front of the spinnerets is a small conical colulus bearing two setae. A sclerotized ring surrounds the colulus and spinnerets. On the ventral surface the ring is enlarged and in the middle is occupied by the tracheal spiracle.

Female (allotype).—Measurements in millimetres:—

Body length	2.86
Length of carapace	0.86
Width of carapace	0.74
Height of carapace	0.63
Length of abdomen	2.00
Width of abdomen	1.49
Length of chelicerae	0.48

Leg	*Femur*	*Patella*	*Tibia*	*Metatarsus*	*Tarsus*	TOTAL
1	0.62	0.22	0.48	0.33	0.39	2.04
2	0.59	0.25	0.44	0.30	0.38	1.96
3	0.44	0.23	0.40	0.30	0.34	1.71
4	0.73	0.33	0.62	0.42	0.41	2.51
Palp	0.19	0.11	0.21	—	0.27	0.78

The female resembles the male in form and general features. Only the following characters need be described.

Chelicerae.—Slightly shorter than those of the male and without stridulating ridges.

Legs.—Length order 4.1.2.3. Clothed with barbed hairs and provided with trichobothria as in the male. The oblique row of five peg-like spines on the retrodorsal side of the femora of the first pair of legs is also present. There are no stridulating ridges on the femora of the second legs.

Palpi.—Clothed with barbed hairs. A single trichobothrium on the tibia is present and a drum on the tarsus. A tarsal claw is absent.

Abdomen.—A dorsal scute is absent. The petiolus is surrounded by a narrow sclerotized ring but there is no plate on the front of the abdomen or covering the epigastrium. On each side behind the epigastric furrow is a longitudinal row of five small sclerites, the two rows converging towards the spinnerets. Between the two rows and immediately behind the epigastric furrow are two larger oval sclerites, one behind each lung cover. In the middle of the ventral surface are four circular sclerites forming a quadrangle as in the male. The tracheal spiracle opens on a single sclerite in front of the colulus and spinnerets, but there is no sclerotized ring surrounding the spinnerets (fig. 14). The epigynum has the form shown in figure 15.

Occurrence.—The holotype male and allotype female were found under the loose bark on eucalypts at the Domain, Hobart, Tasmania. The male was collected 24 May 1937 and the female in March 1955.

Parachaea saxicola sp. n.

(Figs 16-20)

Male (holotype).—Measurements in millimetres:—

Body length	2.17
Length of carapace	0.91
Width of carapace	0.69
Height of carapace	0.79
Length of abdomen	1.31
Width of abdomen	1.03
Length of chelicerae	0.52

Leg	*Femur*	*Patella*	*Tibia*	*Metatarsus*	*Tarsus*	TOTAL
1	0.55	0.25	0.48	0.33	0.44	2.05
2	0.60	0.26	0.47	0.29	0.41	2.03
3	0.55	0.23	0.41	0.28	0.38	1.85
4	0.69	0.29	0.59	0.38	0.41	2.36
Palp	0.21	0.11	0.23	—	0.36	0.91

Colour.—Mainly yellowish brown with the chelicerae, femora, tibiae, metatarsi and tarsi somewhat darker.

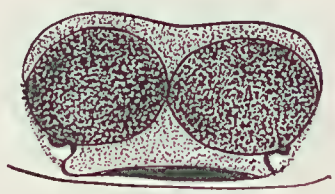
Carapace.—Higher than wide. Posteriorly it descends steeply and is slightly indented (fig. 16). The cephalic part is rounded above and lightly clothed with barbed hairs that slope forward.

Eyes.—The eight eyes are mounted on black rims and form two transverse rows. When viewed from above the front row appears slightly recurved and the hind row slightly procurved. The eye ratio AME : ALE : PME : PLE = 7 : 6 : 5 : 7. The AME are mounted on a black tubercle and separated from each other and from ALE by 6/7 of their diameter. The PME are separated from each other by three times their diameter and from PLE by 6/5 of their diameter. The lateral eyes are contiguous. The median ocular quadrangle is wider behind than in front in ratio 6 : 5, and its posterior width is greater than its length in ratio 24 : 17. The height of the clypeus is about equal to the diameter of AME.

Chelicerae.—Almost as long as the femora of the first legs. They are moderately stout, constricted at the base and devoid of lateral condyles. The front or prolateral surface is provided with transverse stridulating ridges. The fang is short and strongly curved. The furrow shallow and indistinct. There are nine small rod-like teeth on the promargin and slightly in front of the basal three there is a short row of three larger teeth (fig. 17). The dentition is similar to that in the preceding species, *Pararchaea corticola.* On the inner or ventral surface there is a long lamella. Fourteen long setae arranged in a double row are present on the retrolateral surface.

Maxillae.—Strongly convergent over front of labium. The apex is pointed and furnished with a scopula. A well developed serrula is present.

Labium.—Immobile, fused to the sternum, wider than long and furnished with three pairs of setae. The basal half of the labium is sclerotized and the distal half membranous.



Pararchaea saxicola sp.n.

FIG. 16.—Lateral view of body of male
FIG. 17.—Retrolateral view of male chelicera
FIG. 18.—Retrolateral view of femur of first leg
FIG. 19.—Retrolateral view of male palp
FIG. 20.—Epigynum

Sternum.—Longer than wide in ratio 14 : 11, convex, shield-shaped, ending in a rounded point between the fourth coxae. The surface has a reticulate or polygonal pattern and is clothed with a few long hairs. The margin is slightly excavated opposite the bases of the coxae.

Legs.—Length order 4.1.2.3. Moderately short and stout. Lightly clothed with barbed hairs. On the femora of the first legs there is an oblique row of five short peg-like spines on the retrodorsal surface of the basal half (fig. 18). A drum is present on each tarsus. A single trichobothrium occurs on each metatarsus, three on the first and second tibia, two on the third and four on the fourth. Three tarsal claws and accessory claws are present. The upper claws are similar and have three teeth on the basal half. The lower claw is strongly bent and has a single tooth.

Palpi.—Lightly clothed with barbed hairs. There are no apophyses on femur, patella or tibia (fig. 19). The tarsus is spoon-shaped and has a large hook-like apophysis at the base on the retrolateral side. On the inner side of the apophysis is a short blunt tooth. A trichobothrium is present on the tibia and a drum near the apex of the tarsus. The genital bulb is rounded and the embolus curves round the inner surface.

Abdomen.—Broadly oval with two small and two large rounded sclerites or muscle spots forming a quadrangle on the anterior half of the dorsal surface. There is no dorsal scute. The front of the abdomen has a large sclerotized plate, which surrounds the petiolus and extends posteriorly to cover the epigastrium. Behind the epigastric furrow is a narrow transverse sclerotized bar. Four muscle spots form a quadrangle in the middle of the ventral surface. The six spinnerets and a small colulus are surrounded by a narrow sclerotized ring. The tracheal aperture is situated in the ventral part of the ring. The colulus is conical and bears two setae. The surface of the abdomen is clothed with barbed hairs.

Female (allotype).—Measurements in millimetres:—

Body length	3.20
Length of carapace	1.14
Width of carapace	0.91
Height of carapace	0.82
Length of abdomen	2.17
Width of abdomen	1.71
Length of chelicerae	0.63

Leg	*Femur*	*Patella*	*Tibia*	*Metatarsus*	*Tarsus*	TOTAL
1	0.62	0.29	0.51	0.36	0.45	2.23
2	0.60	0.29	0.51	0.33	0.41	2.14
3	0.55	0.27	0.45	0.31	0.41	1.99
4	0.79	0.34	0.70	0.46	0.48	2.77
Palp	0.22	0.12	0.21	—	0.25	0.80

The female resembles the male in colour and appearance but is slightly larger.

Chelicerae.—The form and dentition are as in the male but stridulating ridges on the prolateral surface are lacking.

Legs.—Length order 4.1.2.3. Clothed as in the male. There is also an oblique row of five peg-like spines on the retrodorsal side of the basal half of the femur of the first legs. No stridulating ridges are present on the femur of the second legs. There is a drum on each tarsus. A single trichobothrium occurs on each metatarsus, three on the first and second tibiae and four on the third and fourth.

Palpi.—Lightly clothed with barbed hairs. There is a single trichobothrium on the tibia and a drum near the apex of the tarsus. A claw is lacking.

Abdomen.—Four small sclerites or muscle spots form a quadrangle on the dorsal surface as in the male. In the front of the abdomen the petiolus is surrounded by a narrow sclerotized ring and there is no large plate covering the epigastrium. However, in the epigastric region there are several small sclerites separate from the lung covers and epigynum. Near the middle of the ventral surface are four muscle spots forming a quadrangle. The six spinnerets and colulus are surrounded by a circle of separate sclerites and not by a continuous sclerotized ring. The colulus is small and conical and bears two setae. The tracheal aperture is on a small sclerite in front of the colulus. The abdomen is clothed with barbed hairs. The epigynum as in figure 20.

Occurrence.—The holotype male and allotype female were found *in copulo* on the undersurface of a loose stone on the ground at the Domain, Hobart, Tasmania, 4 May 1938.

Pararchaea ornata sp. n.
(Figs 21-24)

Female (holotype).—Measurements in millimetres:—

Body length	1.94
Length of carapace	0.82
Width of carapace	0.57
Height of carapace	0.65
Length of abdomen	1.12
Width of abdomen	0.90
Length of chelicerae	0.45

Leg	*Femur*	*Patella*	*Tibia*	*Metatarsus*	*Tarsus*	TOTAL
1	0.48	0.20	0.29	0.22	0.31	1.50
2	0.41	0.19	0.30	0.22	0.27	1.39
3	0.36	0.19	0.25	0.21	0.25	1.26
4	0.52	0.23	0.40	0.27	0.31	1.73
Palp	0.15	0.09	0.16	—	0.18	0.58

Colour.—Carapace yellow with the thoracic part dark brown on each side. Chelicerae yellowish brown. Maxillae, labium and sternum yellow. Legs yellow except metatarsi and tarsi which are mainly dark brown. Abdomen yellow with a dark brown median stripe on the anterior half of the dorsal surface and four transverse dark chevrons on the posterior half (fig. 21). On each side of the abdomen is a large dark brown area. A pair of brown muscle spots occur one on each side of the posterior end of the median dorsal stripe. On the ventral surface the epigynum is dark brown; lung covers, sclerites and spinnerets yellowish brown.

Carapace.—Higher than wide, sloping forward with the posterior surface very steep and slightly indented (fig. 22). The upper part of the cephalic region is furnished with a few long barbed hairs.

Eyes.—The eight eyes are arranged in two transverse rows. When viewed from above the front row appears slightly recurved and the hind row procurved. The AME are dark and mounted on wide black rims. They are directed forwards and outwards. The other eyes are pearly white and

also surrounded by black rims. The eye ratio AME : ALE : PME : PLE = 5 : 5 : 5 : 6. The AME are separated from each other by 6/5 of their diameter and from ALE by once their diameter. The PME are separated from each other by 11/5 of their diameter and from PLE by once their diameter. The lateral eyes are contiguous. The median ocular quadrangle is wider behind than in front in ratio 4 : 3 and its length is about equal to its anterior width. The height of the clypeus is equal to the diameter of AME.

Chelicerae.—Long, moderately stout, constricted near the base and without lateral condyles. The fang is short and well curved. The furrow indistinct. As in the preceding species there are two rows of teeth on the prolateral side, one row slightly in front of the other. The hinder row has nine small rod-like teeth and the other row three larger teeth which are opposite the basal teeth of the hinder row and in front of them. When the fang is closed it lies behind both rows of teeth. There are no teeth on the retrolateral side. A thin lamina extends along the ventral or inner surface of the chelicera. Two rows of long thin bristles occur on the retrolateral side.

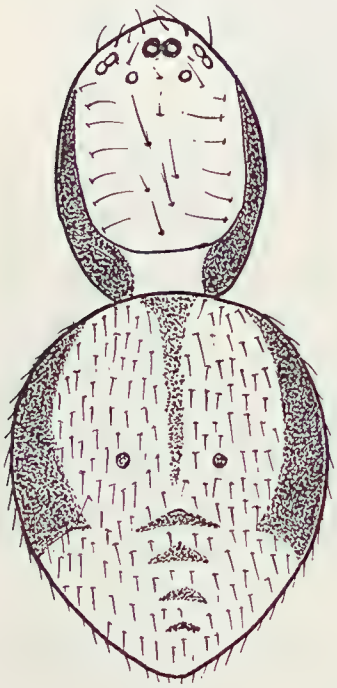
Maxillae.—Strongly converging over the front of the labium. An apical scopula and well developed serrula are present.

Labium.—Wider than long and somewhat pointed in front. It is provided with a few barbed hairs. It is fused to the sternum and appears to be immobile.

Sternum.—Shield-shaped, convex, longer than wide in ratio 11 : 9 and ending in a blunt point between the fourth coxae, which are well separated. The margin is excavated opposite the bases of the coxae. The surface is marked with a polygonal pattern and provided with a few long hairs.

Legs.—Length order 4.1.2.3. Integument somewhat rugose, lightly clothed with barbed hairs. An oblique row of five short peg-like spines is present on the retrodorsal side of the femora of the first legs, but there are no stridulating ridges on the femora of the second pair. There is a drum on each tarsus. A single trichobothrium is present on each metatarsus, three on the first and second tibiae, two on the third and four on the fourth. Three tarsal claws and accessory claws are present. The upper claws are similar and have three teeth on the basal half. The lower claw is strongly bent and has a single tooth (fig. 23). The trochanters lack a notch.

Palpi.—Short and clothed with barbed hairs. A single trichobothrium is present on the tibia and a drum on the tarsus. A claw is lacking.



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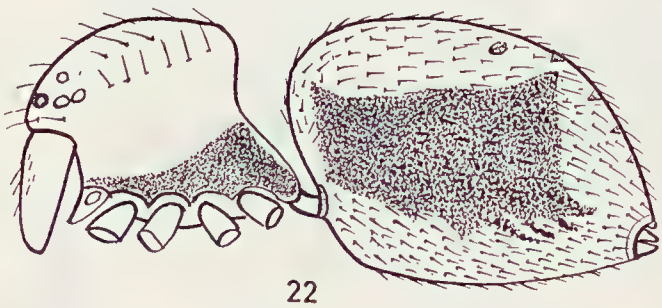

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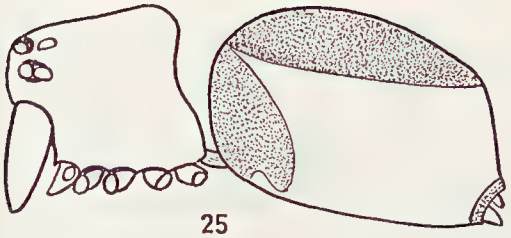
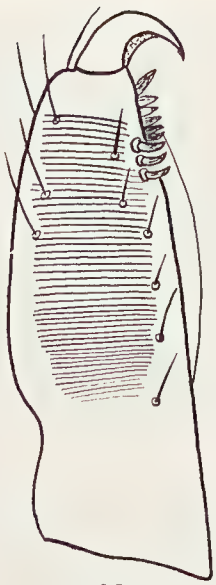
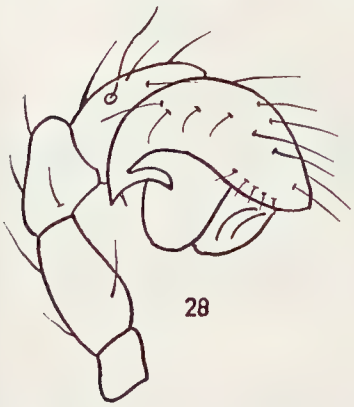
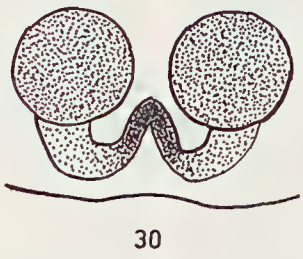
Pararchaea ornata, sp.n.

FIG. 21.—Dorsal view of body of female
FIG. 22.—Lateral view of body of female
FIG. 23.—Tarsal claws.
FIG. 24.—Epigynum









Pararchaea bryophila sp.n.

Fig. 25.—Lateral view of body of male
Fig 26.—Prolateral view of male chelicera
Fig. 27.—Tarsus of first leg of male
Fig. 28—Retrolateral view of male palp
Fig 29.—Colulus
Fig 30.—Epigynum

Abdomen.—Ovoid, clothed with barbed hairs. There are two muscle spots near the middle of the dorsal surface and four in a quadrangle near the middle of the ventral surface. There are no large sclerotized plates but the front of the abdomen has a narrow sclerotized ring round the petiolus. Behind each lung cover is a small sclerite. Six spinnerets and a colulus are present. They are surrounded by a lightly sclerotized ring. The colulus is small and conical. It bears a pair of long setae. The tracheal spiracle opens on a weak sclerite immediately in front of the colulus. The epigynum has the form shown in figure 24.

Occurrence.—The holotype female was taken by shaking gorse (*Ulex europeus*) at the Domain, Hobart, Tasmania, 13 April 1968.

Pararchaea bryophila sp. n.

(Figs 25-30)

Male (holotype).—Measurements in millimetres:—

Body length	1.46
Length of carapace	0.57
Width of carapace	0.46
Height of carapace	0.41
Length of abdomen	0.89
Width of abdomen	0.68
Length of chelicerae	0.30

Leg	*Femur*	*Patella*	*Tibia*	*Metatarsus*	*Tarsus*	Total
1	0.33	0.16	0.23	0.12	0.33	1.17
2	0.27	0.15	0.23	0.12	0.29	1.06
3	0.23	0.14	0.20	0.11	0.25	0.93
4	0.33	0.18	0.31	0.16	0.26	1.24
Palp	0.14	0.11	0.14	—	0.20	0.59

Colour.—Carapace, appendages, sternum and abdominal sclerites tan. Rest of abdomen yellowish.

Carapace.—High, posteriorly almost vertical and slightly indented (fig. 25). Thoracic fovea absent. Dorsal surface sloping slightly towards the front and clothed with a few hairs. Thoracic region marked with a reticulate or polygonal pattern.

Eyes.—Ocular area occupies the full width of the carapace. The eight eyes are arranged in two transverse rows. When viewed from above the front row appears slightly recurved and the hind row almost straight. The eye ratio AME : ALE : PME : PLE = 9 : 8 : 7 : 9. The AME are mounted on a black tubercle and separated from each other by 8/9 and from ALE by 2/9 of their diameter. The lateral eyes are contiguous. PME are separated from each other by twice their diameter and from PLE by 6/7 of their diameter. The median ocular quadrangle is wider behind than in front in ratio 23 : 21 and its length is equal to its anterior width. The AME are dark, the other eyes pearly white. The height of the clypeus is equal to 11/9 of the diameter of AME.

Chelicerae.—Long, moderately stout, constricted near the base and without lateral condyles. Stridulating ridges are present on the front or prolateral surface (fig. 26). The fang is short, strong and well curved. The furrow is shallow and indistinct. There are two rows of teeth on the promarginal side. The first row consists of seven short rod-like teeth close together and the second row of three larger curved teeth, which are situated slightly in front of the basal end of the

first row. All the teeth are on the prolateral side of the fang when it is closed and there are no teeth on the retrolateral side. On the inner or ventral side of the chelicera there is a long lamina. There are a few short barbed hairs on the prolateral surface and a double row of long barbed setae on the retrolateral surface.

Maxillae.—Strongly convergent over the front of the labium and provided with an apical scopula and a well developed serrula.

Labium.—Immobile being fused to the sternum. It is wider than long with parallel sides and pointed in front. The surface has a few coarse hairs.

Sternum.—Longer than wide in ratio 25 : 22, shield-shape, and ending in a bluntly rounded point between the fourth coxae. The surface is convex and marked with a reticulate or polygonal pattern. The margin is slightly excavated opposite the bases of the coxae.

Legs.—Length order 4.1.2.3. The tarsi of the first legs are distinctly swollen in the basal half becoming narrower towards the apex (fig. 27). Each tarsus is provided with a drum on the basal half of the dorsal surface. A single trichobothrium is present on each metatarsus, three on the first and fourth tibiae and two on the second and third tibiae. The legs are lightly clothed with barbed hairs. The short peg-like spines found on the first femora of some species are absent. Three tarsal claws are present. The upper claws are similar and have two teeth in the basal half. The lower claw has a single tooth.

Palpi.—About twice the length of the chelicerae. Femur, patella and tibia are devoid of apophyses. A single trichobothrium is present on the tibia. The tarsus is spoon-shaped and, near the base, its retrolateral margin is produced into a hook-like apophysis, which rests against the genital bulb and is provided with a sharp spine on the inner side (fig. 28). The median division of the bulb has a group of small dentiform spines.

Abdomen.—Ovoid, lightly clothed with finely barbed hairs and provided with a scute that covers about three quarters of the dorsal surface. The front of the abdomen is also covered by a sclerotized shield, which surrounds the petiolus and covers the epigastrium on each side. Above the petiolus it extends upward to meet the front of the dorsal scute. There are six spinnerets and a colulus. The anterior pair of spinnerets are the largest and have a very short terminal segment. The colulus is small and conical (fig. 29). It bears two setae. A sclerotized ring surrounds the spinnerets and colulus. In front of the colulus is the tracheal spiracle, which leads into two pairs of tracheal tubes, which are confined to the abdomen. Near the middle of the ventral surface are four muscle spots arranged in a quadrangle.

Female (allotype).—Measurements in millimetres:—

Body length	1.72
Length of carapace	0.62
Width of carapace	0.49
Height of carapace	0.38
Length of abdomen	1.10
Width of abdomen	0.89
Length of chelicerae	0.30

Leg	*Femur*	*Patella*	*Tibia*	*Metatarsus*	*Tarsus*	TOTAL
1	0.34	0.15	0.25	0.14	0.27	1.15
2	0.29	0.15	0.23	0.12	0.25	1.04
3	0.25	0.12	0.21	0.10	0.22	0.90
4	0.36	0.16	0.33	0.16	0.27	1.28
Palp	0.10	0.07	0.10	—	0.10	0.37

The female resembles the male in colour and general appearance. Only the following features need be described.

Chelicerae.—Have the same form as those of the male but lack the stridulating ridges on the prolateral surface.

Palpi.—Lightly clothed with hairs. A single trichobothrium is present on the tibia. A tarsal claw is absent.

Abdomen.—Broadly ovate. No dorsal scute is present and the large sclerotized plate on the front of the abdomen of the male is also absent. However, a narrow sclerotized ring surrounds the petiolus. The spinnerets and colulus are also surrounded by a narrow sclerotized ring. The surface of the abdomen is lightly clothed with hairs, each of which rises from a small circular sclerite. The form of the epigynum is shown in figure 30.

Occurrence.—The holotype male and allotype female were found amongst moss at the Punch Bowl, Launceston, Tasmania; 24 August 1929. The species has also been taken from moss at Fingal, Tarraleah, The Arve Forest and Mount Wellington.

Remarks on the genus *Pararchaea* Forster

The genus *Pararchaea* Forster (1955) was founded on the characters of *Pararchaea alba* Forster from New Zealand. Two other species have been assigned to the genus, namely *P. binnaburra* Forster from Queensland and *P. rubra* (Forster) from New Zealand, the latter species being originally placed in the genus *Zearchaea* Wilton. The four Tasmanian species described in the present paper bring the number recorded to seven.

In his definition of the genus *Pararchaea* Forster states that the sternum is 'wider than long'. This appears to be an error since in the three species, which he assigns to the genus, the sternum is described as longer than wide, which is also the case in the four Tasmanian species. Furthermore, in the diagnosis the chelicerae are said to have teeth on both pro- and retromargins. However, the description of *P. rubra* (Forster) states 'The cheliceral groove is shallow and armed on the retromargin with a row of eight small teeth which extend from the base of the fang to the tip. There is a further more lateral group of three similar teeth. Pro-margin smooth'. This statement does not agree with figure 12, plate XLI (Forster, 1949), which shows all the teeth to be on the promarginal side and not on the retromargin. In the four Tasmanian species the teeth are likewise on the promarginal side. This appears to be a generic character and a re-examination of the other species seems desirable. The definition of the genus also states that a colulus is absent. However, in the four Tasmanian species a small conical colulus bearing two setae is present.

Lehtinen (1967) considers that a new family Mecysmaucheniidae should be established for the genera *Pararchaea* Foster, *Zearchaea* Wilton and *Mecysmauchenius* Simon.

TYPE SPECIMENS

The holotypes and allotypes of the species described in the present paper will be lodged in the Australian Museum, Sydney.

ACKNOWLEDGMENTS

I am indebted to Mr C. L. Wilton for specimens of *Laestrygones albiceris* Urquhart from New Zealand.

REFERENCES

BONNET, P., 1957—Bibliographia Araneorum. T.2, (G-M).

FORSTER, R. R., 1949—New Zealand Spiders of the Family Archaeidae. *Rec. Cant. Mus.*, Vol. V, No. 4, pp. 193-203, Plates XL-XLII.

————————, 1955(a)—Spiders from the subantarctic islands of New Zealand. *Rec. Dom. Mus.*, Vol. 2, pp. 167-203.

————————, 1955(b)—Spiders of the Family Archaeidae from Australia and New Zealand. *Trans. Roy. Soc. N.Z.*, Vol. 83,, pp. 391-403.

————————, 1964(a)—Aranea and Opiliones of the subantarctic islands of New Zealand. *Pacific Insects Monograph* 7, pp. 58-115.

————————, 1964(b)—The spider family Toxopidae (Araneae). *Ann. Natal. Mus.* Vol. 16, pp. 113-151.

LEHTINEN, P. T., 1967—Classification of the Cribellate Spiders and some allied families, with notes on the evolution of the suborder Araneomorpha. *Ann. Zool. Fenn.* Vol. 4, pp. 199-468.

URQUHART, A. T., 1894—Descriptions of New Species of Araneae. *Trans. N.Z. Inst.* Vol. 26, pp. 204-218.

WILTON, C. L., 1946—A new spider of the family Archaeidae from New Zealand. *Dom. Mus. Rec. Entom.* Vol. 1, pp. 19-26.

THE TASMANIAN JOURNAL OF NATURAL SCIENCE

By

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ABSTRACT

The dates of publication of the separate parts of the *Tasmanian Journal of Natural Science* have been determined.

Some comment is made on the history of the publication of the *Journal*, on the quality of the articles and their scientific value, and on a few of the contributions.

The Tasmanian journal of natural science, agriculture, statistics, etc., was the first scientific periodical of any consequence* to be published in the Australian colonies. The standard of the contributions is high, as one might expect from a society whose patron and guide was Sir John Franklin. (See also Tasmanian State Archives, GO 33/39, pp. 644-653.)

The journal had its origins in the Philosophical Society of Tasmania, a semi-private body comprising those who were interested in the development of the natural sciences in Tasmania. At the invitation of the Governor, their meetings soon came to be held in the library at Government House, 'where every facility and encouragement have been afforded them by their distinguished patron, Sir John Franklin; who has taken the liveliest interest in their proceedings' (Little, J. (1841) Introductory paper. *Tas. J. nat. Sci.*, Vol. I, No. I, pp. 1-13).

The Society had two classes of members, resident and corresponding. The resident members were at first nearly confined to Hobart, but as time went on members from Launceston and other parts of Tasmania, at first included among the corresponding members, were added to the Hobart members, increasing the number of resident members from about a dozen to about thirty. The resident members were largely local dignitaries—government officials, service officers, schoolmasters, medical men—who were interested in the natural sciences, but they included several who were active in their scientific pursuits, such as Lieutenant J. H. Kay, R.N., who was in charge of the magnetic observatory at Hobart, Dr Edmund Hobson, a keen naturalist, and Ronald Campbell Gunn, the botanist.

Among the corresponding members there were a number of scientists of international repute, and Sir John Franklin must have been largely the one who secured their enrolment. They included a number of those who had accompanied the exploring expeditions, both British and French, which visited Tasmania while Sir John was Governor, together with one or two figures of importance in the United Kingdom. Among those who had come with the expeditions were Joseph Dalton Hooker, C. H. Jacquinot, J. B. Jukes, James Clark Ross and J. Lort Stokes; amongst residents in Australia and New Zealand, W. B. Clarke the geologist and Charles Sturt the explorer; and amongst overseas notables, Professor William Buckland the geologist, Professor Richard Owen the anatomist and P. E. de Strzelecki.

The Society took a wide view of its functions in the colony: its object, according to the preface to the first number of the *Journal*, was to encourage scientific research in Tasmania—

> *The publication of our Transactions is, perhaps, the most important field of action for our body: it stimulates to study, and assists research,—it shows how far we are from the fulfilment of all we wish and hope, and yet how much a very moderate degree of diligence avails to diminish the interval.*

The *Tasmanian Journal* published material dealing not only with Tasmania, but also with the other Australian colonies; and as well there were a few contributions relating to New Zealand, the antarctic regions and elsewhere. All the natural sciences were covered—geology, palaeontology, botany and zoology—and there were also articles on exploration and travel, and on a wide range of other subjects. Many of the articles are useful contributions to knowledge of the southern environment. Of Tasmanian interest are papers dealing with *Callorhynchus australis*, by E. C. Hobson (Vol. I, No. I); fossil wood, by Joseph D. Hooker (I/I); Tasmanian plants available as food for man, by R. C. Gunn (I/I); description of fish collected at Port Arthur, by J. Richardson (I/I, II); observations on *Physalia pelagica*, by A. Sinclair (I/II); the pouch young of marsupials, by E. S. P. Bedford (I/III); the aborigines of Tasmania, by Thomas Dove (I/IV), by Jorgen Jorgenson (I/IV), R. C. Gunn (II/X), and W. B. Davies (II/XI); the teeth and poison apparatus of Tasmanian snakes, J. W. Agnew (II/VIII); the acacias of Tasmania, R. C. Gunn (III/I); and several papers describing work at the Hobart observatory, by J. H. Kay (I/II, I/III, II/XI). Papers dealing with the southern hemisphere include—the habits of *Alectura lathami*, the bush turkey of Australia, John Gould (I/I); the geology of Kerguelen, R. McCormick (I/I); a vocabulary of the Adelaide tribe, J. P. Gell (I/II); Australian coals, P. E. de Strzelecki (I/III); the

* Possibly some may consider that such publications as the Anniversary Addresses of the Agricultural Society of New South Wales (1823, 1824, 1826) and the reports of the Agricultural and Horticultural Society of New South Wales (1828, 1829, 1830) should be classified as scientific periodicals and accorded priority, but these were certainly not journals concerned with the publication of scientific research, and they did not set out to be such.

antarctic regions, R. McCormick (I/IV); the mythology of the New Zealanders, James Hamlyn (I/IV); the discovery of the bones of the moa and notes on the tuatara, W. Colenso (II/VII); the trilobites of New South Wales, W. B. Clarke (III/I); and the mandible of *Diprotodon*, by E. C. Hobson (III/V). As well there are extracts from articles of Tasmanian interest from the overseas scientific periodicals, and some reports from other sources; and a number of valuable notes on a variety of subjects.

Two zoological papers are of some interest. One is an account of the anatomy of the elephant shark, *Callorhynchus australis* (Holocephali), by E. C. Hobson (I/I). The standard of the work is high. The author describes the external features, skin, skeleton, alimentary canal and reproductive system of a male specimen. He also mentions 'an accessory organ of respiration . . . situated betwixt the posterior rays of the dorsal fin and the spinal column', consisting of 'a fine net-work of vessels enclosed betwixt the two layers of depressor muscles arising from the sides of the spinal column, and inserted into the triangular piece sustaining the fin'. Hobson considered the structure to be a 'rudimentary lung', from being able to squeeze out the gaseous matter contained in it, and believed it to serve the fish 'in the essential movements of sinking and rising to the surface'; and gives his views on how it might function. A preliminary examination of specimens of *C. australis* has shown that a cavity does exist subcutaneously behind the dorsal fin, as Hobson has described. It seems to communicate with a retroperitoneal space along the dorsal wall of the abdominal cavity. The matter is now being investigated further.

The other zoological paper of note, also by Dr Hobson, records some observations on the blood of *Ornithorhynchus* (I/II). He finds the erythrocytes to be of the mammalian type, and describes them, but he concludes erroneously that the Monotremata must be viviparous, not oviparous.

The appearance of the first number of the journal gave rise to some outcry from Hobart's printers because the work was done at the Government Printing Office, which was prohibited from taking private work. Edward Abbott, proprietor of the *Hobart Town Advertiser*, was one of those who protested, and he published his correspondence with the Colonial Secretary in a rare pamphlet, a copy of which is to be found in the Colonial Secretary's files (Tasmanian State Archives CSO 8/21/580). Mr Abbott's objection was—

> *not so much to the Magazine in question, for it is an innocuous production, but it is purely one of principle; for if the Government can be authorised to print a* scientific *Magazine, they may with impunity put forth a* political *Newspaper.*

Mr Abbott's complaint, however, had little substance, because when the Society had reached the decision to publish a journal, R. C. Gunn had made enquiries and had been told by Mr Elliston that the work was beyond the capacity of even the leading printers in the colony because none of them had a sufficient quantity of good type. Moreover, 'the miserable blundering style' in which most of the colony's newspapers were got up gave little hope that any one of them could produce a journal of the 'neatness and accuracy' deemed essential in a scientific periodical (Archives, Royal Society of Tasmania).

The importance of the material published in the *Tasmanian Journal* merits exact information about the dates of issue of the parts. These can be determined largely from advertisements in the Tasmanian newspapers.

Volume I Title page dated 1842

No. I. Pp. 1-80; issued 20 August 1841; edition, 750 copies.

Sources: Secretarys' report, dated 1 September 1841 (archives, Royal Society of Tasmania; *H.T. Courier*, 27 August 1841. September 10.

No. II. Pp. 81-160; issued 9 November 1841.

Sources: *H.T. Courier*, 12 November 1841.

No. III. Pp. 161-240; issued 27 May 1842.

Sources: *H.T. Courier*, 27 May 1842.

No. IV. Pp. 241-320; issued 5 July 1842.

Sources: *H. T. Courier*, 8 July 1842.

No. V. Pp. 321-424; issued 3 February 1843 (paper cover dated 1842).

Sources: *H.T. Courier*, 3 February 1843.

Volume II Title page dated 1846

No. VI. Pp. 1-80; issued 11 August 1843.

Sources: *H.T. Courier*, 11 August 1843.

No. VII. Pp. 81-160; issued 6 October 1843.

Sources: *H.T. Courier*, 6 October 1843.

No. VIII. Pp. 161-240; issued (22) 29 January 1845 (paper cover dated 1844).

Sources: *Launceston Examiner*, 22 and 29 January 1845.

No. IX. Pp. 241-320; title page dated April 1845, but probably not issued before June 1845.

Sources: *T.T. Courier*, 5 June 1845; *Launceston Examiner*, 25 June 1845.

No. X. Pp. 321-392; issued c. 26 November 1845 (title page dated July 1845).

Sources: *Launceston Examiner*, 26 November 1845.

No. XI. Pp. 393-468 (index, pp. 465-467); issued c. 25 March 1846 (title page dated January 1846).

Sources: *Launceston Examiner*, 25 March 1846.

Volume III Title page dated 1849

No. I. Pp. 1-80; issued c. 2 January 1847 (title page dated October 1846).

Sources: *Launceston Examiner*, 2 January 1847.

No. II. Pp. 81-164 (pp. 160-164 not numbered—meteorological register); plates 3-5 (art. XIII) issued with No. III; title page dated 1847).

Sources:

No. III. Pp. 165-248 (pp. 244-248 not numbered—meteorological register) issued (not determined) (title page dated July 1847).

Sources:

No. IV. Pp. 249-327 (plus 7 pages meteorological register, not numbered); issued (not determined) (title page dated January 1848).

Sources:

No. V. Pp. 329-414 (pp. 409-414 not numbered—meteorological register); issued c. 19 August 1848 (title page dated July 1848).

Sources: *Launceston Examiner*, 19 August 1848.

No. VI. Pp. 415-489 (pp. 479-484 not numbered—meteorological register; pp. 485-489, index); issued (not determined) (title page dated January 1849).

Sources:

NOTES:

(1) In volume I (No. II, pp. 81-93, continued in No. III, pp. 161-187) there appeared an article by Captain Arthur F. Cotton* entitled 'On irrigation in Tasmania'. The second part of the article was published in the *Hobart Town Courier* of 6 and 13 May 1842. The arrangement of the work as it appeared in the *Courier* is slightly different from that in the *Journal*, the material of pp. 161-170, 186-187 of the latter printing appearing on 6 May, and that of pp. 171-186 on 13 May. The engraved plates of the *Journal* articles were issued with the *Courier* of 6 May 1842, and here include a view of a dam which is not found in the *Journal*. The same article, but without the plates was also published in the *Van Diemen's Land Chronicle* of 4 March (see also *H.T. Courier* of 18 March 1842). Irrigation was also the subject of a lecture given by Major Hugh C. Cotton at the Mechanics' Institute, Hobart, on 14 July 1843. At the request of the committee of the institute, the address was later published by George Rolwegen, bookseller, Collins Street, Hobart, being issued on 6 October 1843 (see *H.T. Courier*, 6 October 1843) J. A. Ferguson, *Bibliography of Australia*, 3, item 3594).

In spite of the similarity of name, origin and subject, Captain Arthur Cotton and Major Hugh Cotton were different people. Captain Arthur T. Cotton of the Madras Engineers arrived in Tasmania in October 1841, married and settled at Longford: he had had twenty years experience of irrigation works in India. His paper on irrigation in Tasmania was published in two parts, the first appearing in November 1841 and the second in May 1842—publication of the second part was therefore anticipated by the *Chronicle* and the *Courier*. Captain Cotton was a corresponding member of the Tasmanian Society at the time of issue of the first number of the *Journal*. In 1854 he sold Longford House and returned to India. Major H. C. Cotton did not reach Tasmania until 10 November 1842. He also had been in India, but he came to Tasmania to settle, having been appointed deputy surveyor-general. Major Cotton was not elected to membership of the Tasmanian Society until August 1843.

(2) The separate numbers of the *Tasmanian Journal*, of which some in original covers are still to be found in collections, were issued in brown, greenish blue or yellow paper wrappers showing title and medallion (a platypus encircled by a belt inscribed with the motto 'quocunque aspicias hic paradoxus erit', paradoxus being a pun on the name *Ornithorhynchus paradoxus*); volume number, and month and year of issue (in the earlier numbers, the year of issue only); the publisher and printer. Volumes I (all) and II (numbers VI and VII) were published and printed by James Barnard, Government Printer; and Volumes II (numbers VIII and XI) and III (all) by Henry Dowling, Launceston. Henry Dowling's titles are given variously: e.g., Henry Dowling, Printer, Launceston, and Henry Dowling, Stationer, Launceston; and sometimes the press is also noted as "Examiner", Launceston. Volume II, number VII and succeeding numbers were also published by John Marray, London. The secretary for the issue of Volume I numbers I-IV was F. Hartwell Henslowe; for Volume I number V and Volume II numbers VI and II, John Philip Gell; and for all later issues, Ronald Campbell Gunn.

ACKNOWLEDGMENT

I should like to thank Mr K. M. Dallas for checking references for me.

* An MS note seen in a copy of the Journal, apparently contemporary, states—'Must be *Arthur T*'.

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THE MINERALOGY, PETROCHEMISTRY AND MAGMATIC HISTORY OF THE TAMAR LAVAS, NORTHERN TASMANIA

By

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(With four text figures and two plates)

ABSTRACT

The Tertiary lavas of the Tamar Trough are mostly undersaturated to near-saturated alkali olivine-basalts, with minor flows of olivine-nepheliníte, nepheline-basanite, limburgite and tholeiitic olivine-basalt.

Olivine forms the main phenocryst fraction in the lavas, but includes xenocrysts and late intergrowths, and ranges in composition from about Fo_{91} to Fo_{55}. Labradorite Ab_{31-41}, zoned to about Ab_{62}, is the typical feldspar. The clino-pyroxenes are augites, passing into titan-augite and aegirine-augite in the more alkaline rocks. Nepheline is represented in the olivine-nephelinites and basanite, and analcime is a late-stage accessory in the coarser olivine-basalts. The iron ore is ilmenite or titano-magnetite, commonly altered to leucoxene, and other accessory minerals include apatite, zeolites and biotite. The finer grained lavas tend to have glassy mesostases, darkened with iron ore in a few cases, and the coarser lavas commonly show microlitic, feldspathic and zeolitic mesostases.

Some of the lavas carry peridotitic xenoliths and xenocrysts, composed mostly of magnesian olivine, with some clino-pyroxene and spinel, and basalt at Corra Linn contains augite xenocrysts from depth, showing well developed reaction rims. Accidental xenoliths in the lavas include fused dolerite and sediments, in part replaced by clino-pyroxene.

Differentiation trends can be distinguished in the Tamar suite, both between separate lavas and within individual lavas. Differentiation within thick lavas of coarse basalt has produced picritic, mesostasis-rich and pegmatitic phases, and comparisons are made with differentiated rocks of similar compositions in sills and necks elsewhere in Australia.

The Tamar volcanic suite is predominantly an alkaline association, resembling the Older Volcanics of Victoria, the Auckland Basalts of New Zealand, and, to some extent, the Hawaiian alkali basalts.

The Tamar eruptions commenced about Upper Eocene time, with the initial alkali basalt magma ascending in a relatively undifferentiated state, before undergoing some differentiation prior to further eruption. Olivine-nephelinite then appears to have erupted, probably in the Oligocene and possibly during waning in the volcanism, before renewed and more wide-spread eruption of olivine-basalts in about Middle Tertiary time. Fractionation of augite, and possibly olivine, or spinel, at depth may have played a part in producing the magmas for these later lavas, with some low pressure differentiation giving the coarse olivine-basalts of the capping flows

The Tamar lavas form part of an alkaline volcanic association extending to the west, and pass transitionally into an olivine-tholeiite association to the east and south-east. The parent alkali basalt magmas possibly formed from relatively restricted partial mantle melting, with segregation of magma at depths of 35-70 Kms; olivine-tholeiite parent magmas on the south-eastern outskirts possibly formed from a greater degree of melting.

INTRODUCTION

Tertiary lavas outcrop along much of the Tamar Trough, a fault structure formed in or prior to the Palaeocene (Longman, 1966; Sutherland, 1966). This paper discusses the mineralogy, petrochemistry and magmatic history of these lavas, based on detailed geological and petrographic studies to be presented elsewhere; the petrography of the lavas is summarized here in a series of photomicrographic plates (Plates 1-12).

Numerous persons have assisted in the work as a whole, and more complete acknowledgment will be given elsewhere. However, the author would like to thank the following for assistance in aspects of this particular paper in regard to discussion, criticism and chemical data:—Dr R. Varne, Mr D McP. Duncan, Mr R. J. Ford, Mr M. R. Banks, and Mr C. Gee (Geology Department, University of Tasmania); Mr I. B. Jennings and Mr D. I. Groves (Tasmanian Department of Mines); Dr D. H. Green, Dr I. McDougall and Mr N. Gray, Department of Geology and Geophysics, Australian National University); Dr A. H. Spry (A.M.D.L., Adelaide, South Australia); and Mr P. Brumby, Mr F. Brown and Mrs G. Sanders. Mr W. Peterson (Geology Department, University of Tasmania) assisted with microslide photography, and Mr M. Bower (Tasmanian Museum) helped with preparation of rocks for analysis. This work represents part of an M.Sc. thesis submitted by the author to the University of Tasmania.

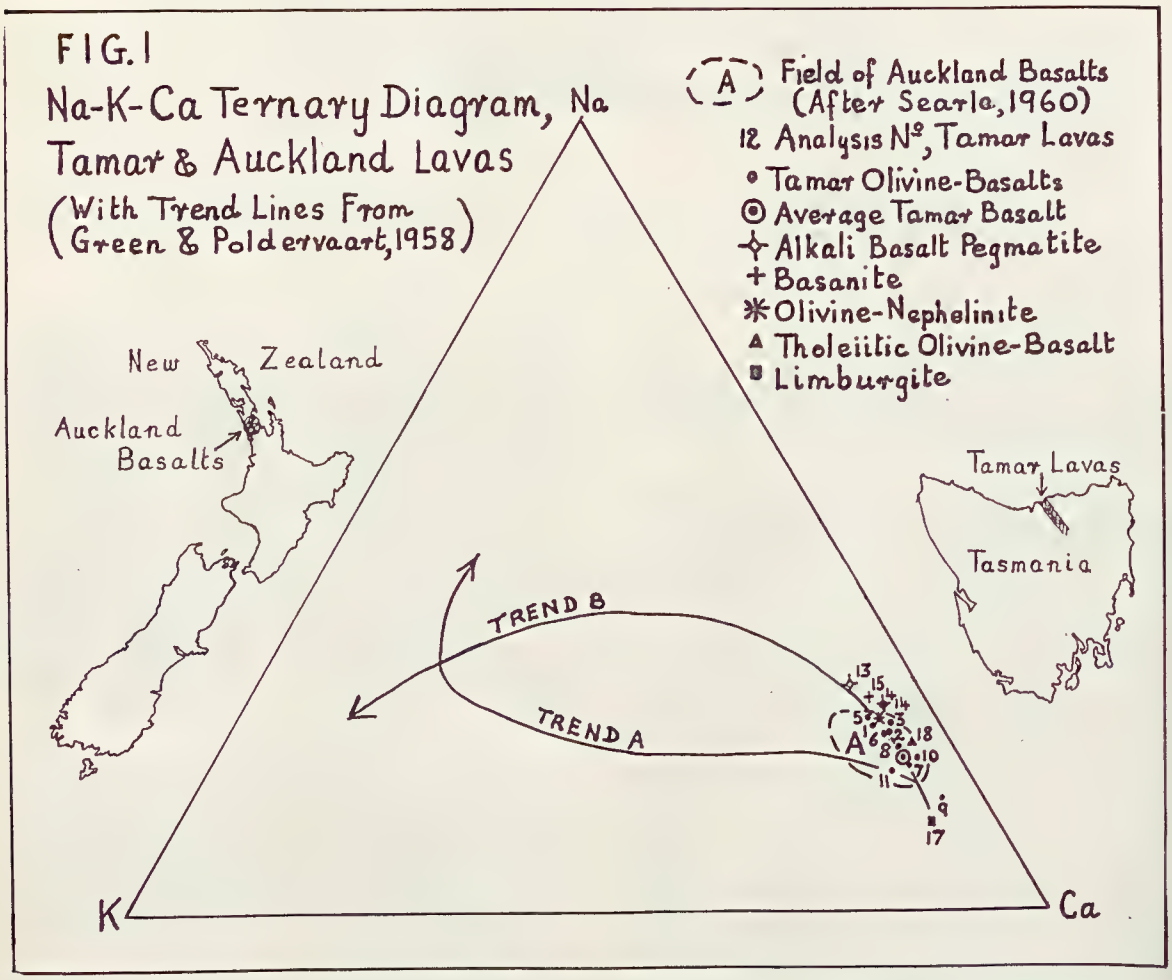

FIGURE 1—N.-K-Ca ternary chemical variation diagram of Tamar lavas, compared with the field of the Auckland basalts and the trend lines of Green and Poldervaart, 1958 (modified from Searle, 1960).

MINERALOGY AND ORDER OF CRYSTALLISATION IN THE TAMAR LAVAS

Determination of Mineral Compositions

Compositions of the main minerals crystallising in the Tamar lavas were gauged by the following methods:—Optic axial angles of olivines and pyroxenes were determined on a Leitz four-axis universal stage. Difficulties in determining olivine compositions from 2V measurement (Wyllie, 1959; Munro, 1966) are applicable to the data presented in this study, but numerous measurements were made and clearly aberrant values have been omitted; errors in the $2V_z$ values are probably not greater than $\pm$ 2°, corresponding up to about $\pm$ 4 mol. per cent of Mg_2SiO_4. Measurements of $2V_z$ of the clino-pyroxenes were corrected for refraction errors from the chart of Emmons (1943), using approximate refractive index values, and are probably accurate to within $\pm$ 2°. Refractive indices (β) were determined on crushed grains of some of the olivines and clino-pyroxenes from the coarser rocks, nodules and xenocrysts, using immersion media and a refractometer. Longitudinal extinction angles (Z:c) for the clino-pyroxenes were measured on the universal stage on twinned crystals where possible, and supplemented by measurements in slides from sections showing maximum birefringence and flash optical interference figures.

Compositions of the clino-pyroxenes are only broadly determinable from this optical data, particularly the titan-augites, which show wide variations in optical values and compositions (Deer, Howie and Zussman, 1963). However, compositions of some of the clino-pyroxenes in the Corra Linn basalt were determined by micro-probe analysis, through the courtesy of D. H. Green and N. Gray, Australian National University (Table 2).

Plagioclase compositions were estimated from maximum symmetrical extinction angles on albite twins, in conjunction with the determinative procedures of Rittmann and El-Hinnawi (1961). Opaque iron oxides were identified from polished thin sections by reflected light microscope. Potash-bearing feldspars and analcimes were confirmed in a number of cases by etching with HF and staining with sodium cobaltinitrite. Amygdale minerals were determined from optical properties in slides and by X-ray powder photography in a number of cases.

Olivines

The order of crystallisation observed in the Tamar lavas clearly indicates that much of the olivine was present at an early stage, and had suffered partial solution prior to both extrusion and final consolidation, giving corroded phenocrysts. Crystallisation, however, was progressive and separation continued on extrusion, as in almost all cases the phenocryst fraction grades down into groundmass grains. The olivine shows differing degrees of alteration to serpentine, 'bowlingite', carbonates, chlorite and iron ore, and this is marked in the late-stage crystallisations of the coarse lavas.

The olivine ranges from forsterite to hyalosiderite in composition ($2V_z$ 86-105°, $\simeq Fo_{94-55}$), with the majority of the crystals showing $2V_z$ between 88-95° ($\simeq Fo_{91-76}$). Much of the olivine is zoned, commonly showing more forsteritic cores, and the most fayalitic olivine occurs in the late-stage pegmatites in the coarse lavas ($2V_z$ 95-105°, β 1.730-1.741 $\pm$ 0.002, $\simeq Fo_{76-55}$). In many rocks some of the phenocrystic olivine shows strain polarisation and translation lamellae, and clearly includes xenocrysts derived from peridotitic xenoliths, described later.

Feldspars

The initial plagioclase crystallised in the Tamar basalts is invariably labradorite, with a composition of about Ab_{38-44}, which on continued crystallisation developed more sodic outer zones, reaching compositions of up to about Ab_{62}. Twinning on the albite, Carlsbad and pericline laws is common. Under conditions of slow cooling that prevailed in the thicker lavas, the plagioclase grew to considerable size, with crystals reaching over a centimetre in length in the coarsest rocks. Investigations of the plagioclases, using the zonal method of Rittmann and El-Hinnawi (1961), indicate that they are high to intermediate-temperature types, including those in the late pegmatitic phases. Some incipient analcimisation of the plagioclase occurs in the coarse analcime bearing basalts.

Late-stage feldspars, with low refractive indices, and commonly negative optical sign and undulose extinction, are developed interstitially in some of the basalts. Their compositions have not been precisely determined, but they include alkali feldspars and sodic plagioclases. Alkali feldspar is a common component in the microlitic mesostasis found in some of the basalts, and also forms overgrowths on plagioclase in the pegmatitic phases of the coarse basalts.

Iron Ore

This is commonly ilmenite or titano-magnetite, generally altered to leucoxene. Its separation covers a wide range during the crystallisation of the lavas. In some cases separation commenced at a very early stage to form the small inclusions within olivine phenocrysts. Much of the iron ore is euhedral to subhedral and crystallised on extrusion, but many of the rocks also show iron ore moulding groundmass minerals and forming skeletal or long lath-like crystals typical of late-stage crystallisation. Finally, in many cases, the mesostases in the rocks are charged with crystallites and globules representing the incipient crystallisation of iron ore just prior to solidification.

Clino-pyroxenes

The clino-pyroxenes in the Tamar lavas include augite, titan-augite and aegirine-augite, and show a wide range in optical properties and textures, reflecting considerable variation in composition and a complex pattern of crystallisation. This is discussed here at some length, but some of the conclusions inferred from the optical data require confirmation by further chemical analyses. Three distinct stages of clino-pyroxene crystallisation can be recognised in the Tamar lavas.

The first stage involved the crystallisation of aluminous augite ($2V_z$ 50-56°, Z:c 47-49°, β 1.698-1.700 $\pm$ 0.002) relatively high in sodium and low in calcium content (analyses 1 and 2, Table 2), and is represented as remnant xenocryst cores in the Corra Linn basalt. The chemistry of this augite is consistent with its crystallisation at high pressure, suggesting that the crystals probably separated in the magma at depth and possibly represent the liquidus phase (D. H. Green, pers. comm.). The crystals were presumably carried to the surface out of equilibrium by a rapid ascent of the magma.

The second stage of clino-pyroxene crystallisation is represented by the crystallisation of augite in reaction rims around the augite xenocrysts. This augite ($2V_z$ 50-62°, Z:c 44-52°; analysis 3, Table 2) is lower in alumina and soda and higher in lime compared with the augite cores, and presumably crystallised at lower pressures following reaction and resorption of the cores as the magma rose to higher levels.

The third stage of clino-pyroxene crystallisation is represented by the normal separation of clino-pyroxene about the time of extrusion, and in the Corra Linn basalt this pyroxene mantles the augite of the xenocrysts and their reaction rims. This stage commenced after considerable separation of olivine and usually more or less simultaneously with the crystallisation of plagioclase. In part of the tholeiitic olivine-basalt from TEX Hill, crystallisation of the clino-pyroxene and feldspar had barely commenced upon chilling into a glassy base containing crystallites and skeletal crystals of these minerals. In the olivine-basalts of the lower Tamar area the crystallisation of the two minerals commenced on extrusion and olivine is the only phenocryst fraction. The porphyritic texture in the basalt at East Arm, correlated with the upper olivine-basalt in the lower Tamar, is interpreted as resulting from prolonged growth of feldspar,

and to a lesser extent the pyroxene, below more slowly cooling lava within the neighbourhood of a feeder vent. On the other hand, in the later, widespread, undersaturated olivine-basalts and analcime bearing coarse olivine-basalts, the clino-pyroxene appears to have begun crystallisation by the time of extrusion, giving sporadic, glomeroporphyritic, partly corrosion-riddled phenocrysts, and small, euhedral micro-phenocrysts in the finer grained and chilled contact rocks. Once started, the separation and growth of clino-pyroxene in the Tamar lavas appears to have progressed until solidification was completed.

In the finer grained lavas the bulk of the pyroxene is intergranular, with only limited or incipient intergrowth with the feldspar. In the coarser grained lavas, however, there is also late-stage crystallisation in large subophitic to ophitic plates, apparently formed from growth in slowly cooling parts of thick flows, aided by the presence of volatile-rich residual fluids. In extreme cases, in the pegmatitic phases, the pyroxenes develop complex graphic and dendritic intergrowths. In the nepheline bearing lavas the feldspathoid crystallised at a fairly late stage compared with much of the pyroxene, so that these rocks show groundmass textures ranging from ophitic to poikilitic and grading to hyaloophitic to hyalopilitic.

The normal clino-pyroxenes in the Tamar lavas are augites that are commonly zoned, generally gradationally; normal, reverse, oscillatory, hour-glass, complex and colour zoning may be developed. Simple and lamellar twinning on 100 and 010 is often present. The augites show wide variations in optic axial and longitudinal extinction angle values; these are discussed here in relation to the probable compositional trends.

The colourless to pale brown augite in some of the olivine-basalts, and the early colourless augite in the partly corrosion riddled phenocrysts and the inner cores of the titan-augites in the more undersaturated and alkaline lavas, generally shows normal zoning in the range of $2V_z$ 53-66° and Z:c 46-54°. This suggests a diopsidic or salitic augite, probably grading to a composition similar to that in the augite overgrowths around the xenocrysts in the Corra Linn basalt (analysis 4, Table 2).

The incorporation of titanium into the augites to give coloration and pleochroism (X pale pink to mauve, Y pink to reddish mauve, Z pale fawn to yellow brown, $Y > X \doteq Z$), no doubt causes complex compositional changes through accompanying balancing substitutions, and gives the wide range observed in optical properties (β 1.705-1.723 $\pm$ 0.002). In many of the Tamar rocks the zoned titan-augites, particularly those of late-stage crystallisation, show a general increase in both optic axial and longitudinal extinction angles from core to rim, within the range $2V_z$ 41-77° (core) to 58-84° (rim) and Z:c 33-62° (core) to 38-66° (rim). The higher values commonly, but not always, correlate with a strengthening of colour and pleochroism in the outer zones. These values range notably higher than the normal limits of $2V_z$ and Z:c for augites (including titan-augites), except for sodian augites (Deer, Howie and Zussman, 1963). This, considered in conjunction with marginal gradation and alteration of a number of these titan-augites into greenish aegirine-augite (Z:a 46-18°; inner zone to rim), suggests that the high values may be due to the incorporation of significant amounts of sodium, possibly as a solid solution of titan-augite and soda-augite. Such intermediate clino-pyroxenes have been described by Yagi (1953) from alkaline rocks in the Sakhalin area, and it is interesting to note that the host dolerites show a similar chemistry to the coarse olivine-basalts of the Tamar suite.

In contrast, some of the titan-augites of the Tamar lavas show a decrease of optic axial angle and an increase of longitudinal extinction angle from core to rim, within the range $2V_z$ 52-66° (core) to 41-53° (rim) and Z:c 34-49° (core) to 38-54° (rim). This tends to occur in the finer grained lavas and is more typical of the normal trend in zoned augite (Wilkinson, 1956b; Deer, Howie and Zussman, 1963); sodium presumably has not entered into these augites to any great degree.

An interesting comparison can be made with the trends in optical behaviour of titan-augites of the Tamar lavas and the similar Auckland basalts of New Zealand (Searle, 1961). The typical titan-augite of the Auckland basalts generally forms small crystals in fine grained lavas, with $2V_z$ 56-72° and Z:c 41-52°, and almost universally the 2V values decrease and Z:c values increase from the inner to outer zones. On the other hand, in rare coarse phases with strongly coloured, zoned titan-augite $2V_z$ and Z:c both increase from paler inner zones to darker outer zones, e.g., in the Domain basanite with $2V_z$ 42-48° (inner zone) to 63-64° (outer zone) and Z:c 47-52° (inner zone) to 54-61° (outer zone). Thus, there is a parallelism in the titan-augite trends of the two suites, but in the Tamar rocks the trend shown by the late-stage titan-augite is much more prominent, probably largely as a result of slower cooling and crystallisation in thicker lavas.

A further trend is also noted in the Tamar rocks in cases where titanium depletion has reversed the typical late-stage trend. These titan-augites have paler coloured outer rims that show a decrease in both $2V_z$ and Z:c within the range $2V_z$ 59-66° (inner zone) to 41-53° (outer zone) and Z:c 47-49° (inner zone) to 41-42° (outer zone). These values suggest that with the titanium depletion sodium may also be lost from the augite structure and accommodated in the residual mesostasis of the rock.

Finally, clino-pyroxenes have crystallised in a number of the Tamar lavas through reaction with incorporated sedimentary xenoliths. This clino-pyroxene occurs within the fused xenoliths and/or around them in reaction rims; sporadic clino-pyroxene aggregates in the rocks probably represent the extreme case of this replacement. The clino-pyroxene is colourless to pale brown or mauve and is commonly prismatic. Measurements on zoned crystals gave $2V_z$ 67° (core) to 58° (rim) and Z:c 43° (core) to 53° (rim). Similar clino-pyroxene replacements are described in xenoliths in the Auckland basalts by Searle (1962) and his detailed remarks on their formation are probably equally applicable to those of the Tamar rocks.

Feldspathoids and Accessory Minerals

Nepheline is represented as a major constituent in the olivine-nephelinites and the nepheline-basanite of the Tamar suite. It generally forms poikilitic areas in a glassy groundmass, but becomes more coarsely crystalline in some phases and forms large zoned crystals up to over 5 mm in length in the nephelinite pegmatite at Spring Bay. No detailed analytical or optical work was done on the nepheline. Analcime occurs in the coarse olivine-basalts as interstitial fillings, and staining tests indicate that some of the analcime is potash-bearing. Apatite is invariably present, ranging from small needles in the mesostasis to coarse elongated prisms. Small prisms and needles of aegirine-augite and small flakes of biotite are common minor accessories in the rocks containing an alkaline mesostasis.

Mesostases

The majority of the Tamar lavas contain glassy or microlitic mesostases that in some cases form a considerable proportion of the rock. Glassy mesostases are developed in the finer grained rocks and microlitic mesostases are best developed in the coarse olivine-basalts. The tholeiitic olivine-basalt from 7EX Hill contains an abundant black, opaque, glassy mesostasis typical of such basalts in Tasmania, but in the alkaline lavas the glassy mesostasis is commonly a clear to cloudy glass containing crystallites, and in some cases passes into a brown glass darkened with incipient crystallisation of iron ore. Four gradational mesostases can be recognised in the coarse basalts. Mesostasis type 1 consists largely of intersertal sodic plagioclase, associated with small prisms and crystallites of titan-augite, commonly altered to aegirine-augite, grains and globules of iron ore, some zeolite and clear glass. Mesostasis type 2 is similar, but zeolite predominates and consists mainly of analcime and fibrous radiating species. Mesostasis type 3 consists of numerous small laths and curved to spherulitic microlites of alkali feldspar, associated with prisms of apatite, small grains and crystallites of iron ore and flakes of biotite, in a zeolitic analcime-rich base containing indeterminate chloritic or serpentinitic material. Mesostasis type 4 resembles type 3, but lacks the indeterminate greenish material. Mesostasis types 3 and 4 are typically developed in the pegmatitic phases, in some cases forming over half the rock. A further mesostasis in the lower olivine-basalt in the lower Tamar consists largely of carbonates (including siderite) and chloritic, nontronitic or serpentinitic clays, and rarely a zeolite resembling chabazite.

Amygdale, Joint and Vein Minerals

Opal, chalcedony, carbonates and clays are common secondary minerals in the tholeiitic olivine-basalt of 7EX Hill and the lower olivine-basalt in the lower Tamar. Zeolites are common in amygdales and veinlets in the alkaline lavas and include natrolite, scolecite, stilbite, thomsonite, phillipsite and chabazite. Other accompanying minerals that may be present are apophyllite, gyrolite, diaspore or gibbsite (?), carbonates and clays. Pyrite coats joint planes in the lower olivine-basalt in the lower Tamar.

Xenoliths

A number of the Tamar lavas carry accidental xenoliths of the country rocks. Small fused and partially replaced pieces of Tertiary sediments are relatively common. Xenoliths of Jurassic dolerite, in which the mesostasis has been partly fused and recrystallised, were noted in the Corra Linn basalt and in the olivine-nephelinite east of St Leonards.

Small peridotite xenoliths occur in the olivine-nephelinites at Spring Bay and east of St Leonards, in the nepheline-basanite at Deviot, in the coarse olivine-basalt on the East Arm foreshore, and in the pyroxene-olivine-basalt at Corra Linn. They are composed mostly of olivine and some clino-pyroxene. The olivine commonly shows strain polarisation and translation lamellae, and gave $2V_z$ 86-94° and β 1.667-1.678 $\pm$ 0.002, indicating compositions within the range Fo_{91-78}, and mostly within Fo_{92-86}. The clino-pyroxene ($2V_z$ 53-67°, Z:c 46-50°, β 1.688-1.692 $\pm$ 0.002) is a colourless, aluminous augite that approaches an endiopsidic composition, judging from the analysis from basalt at Blessington (analysis 6, Table 2). The peridotites also contain minor enstatite, calcic plagioclase ($\simeq Ab_{10-37}$) and green, brown or grey spinels, including ferroan varieties (analysis 5, Table 2).

Similar peridotite nodules are known elsewhere in Tasmania (Sutherland, 1969b), on the Australian mainland (Joplin, 1964) and in New Zealand (Searle, 1961; Black and Brothers, 1965); their distribution is world-wide in basaltic rocks (Green and Ringwood, 1967). Their origin has been disputed; some consider them disrupted segregations and accumulations of crystallates within magma chambers (Searle, 1960-1961; Brothers, 1960; Wager, 1962; etc.), others consider that they are probably derived from the mantle (Turner and Verhoogen, 1960; Wilshire and Binns, 1961, etc.). This question has been reviewed by Black and Brothers (1965) following detailed textural studies on nodules from Tokatoka, New Zealand, and more recently by Green and Ringwood (1967). The latter consider lherzolitic types as remnants derived from the mantle; other types, such as the olivine-augite types in the Tamar lavas, may be genetically distinct.

DIFFERENTIATION IN THE TAMAR LAVAS

Differentiation trends

These can be distinguished in the Tamar suite, both between separate lavas and within individual lavas, by reference to the variation diagram for plots of their solidification index (Kuno, 1959) against SiO_2, Na_2O and K_2O (Figure 4).

The lower olivine-basalt in the lower Tamar (analysis 1, Table 1) plots as the least 'differentiated' of the Tamar lavas on this diagram, suggesting that it may represent a composition close to its parent magma. The Corra Linn basalt with its complement of augite xenocrysts from depth (analysis 9, Table 1) also plots as a little 'differentiated' lava. Another plot with a solidification index over 40 is the picritic phase of the coarse olivine-basalt of the middle Tamar, but in this case differentiation within the basalt itself has spread the apparent values (analyses 4-6 and 13, Table 1), and the average of these suggests slightly 'differentiated' lava.

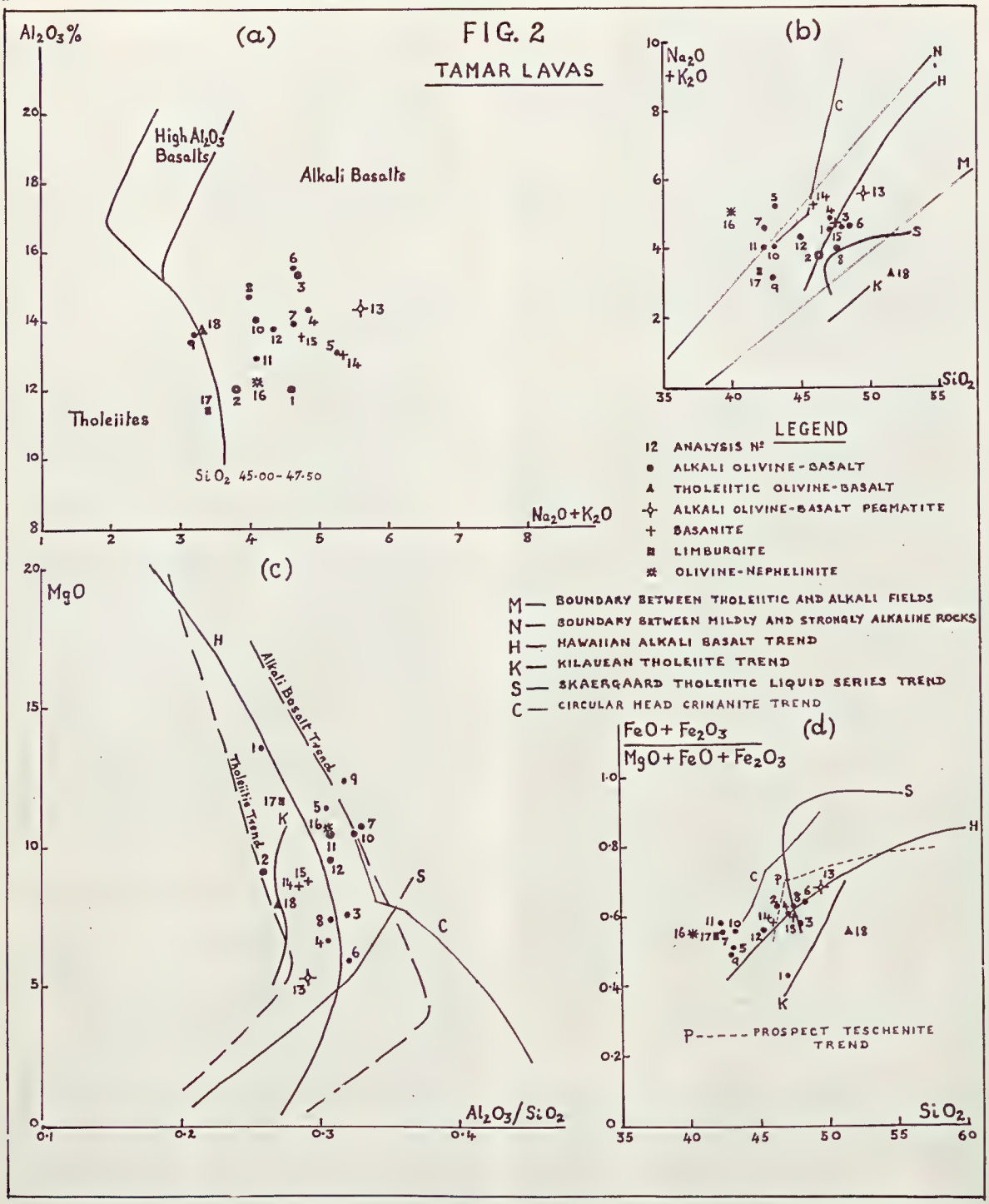

FIGURE 2—Chemical variation diagrams of the Tamar lavas: (a) Al_2O_3 v $Na_2O + K_2O$ with basal field boundaries from Kuno (1960, SiO_2 45.00-47.50); (*b*) $Na_2O + K_2O$ v SiO_2, with tholeiite-alkali basalt boundary (M) from MacDonald and Katsura (1964), and boundary of mildly and strongly alkaline rocks (N) from Saggerson and Williams (1964); (*c*) MgO v Al_2O_3/SiO_2 with alkali basalt and tholeiite trends after Murata (1960); (*d*) FeO + Fe_2O_3/MgO + FeO + Fe_2O_3 v SiO_2; S (trend of Skaergaard liquid series, Wager 1960); K (Kilauean tholeiitic trend, Tilley 1960, Muir and Tilley 1963); H (Hawaiian alkali basalt trend, MacDonald 1949); C (Circular Head crinanite trend, from analyses of Edwards 1941); P (Prospect teschenite trend, Wilshire 1967).

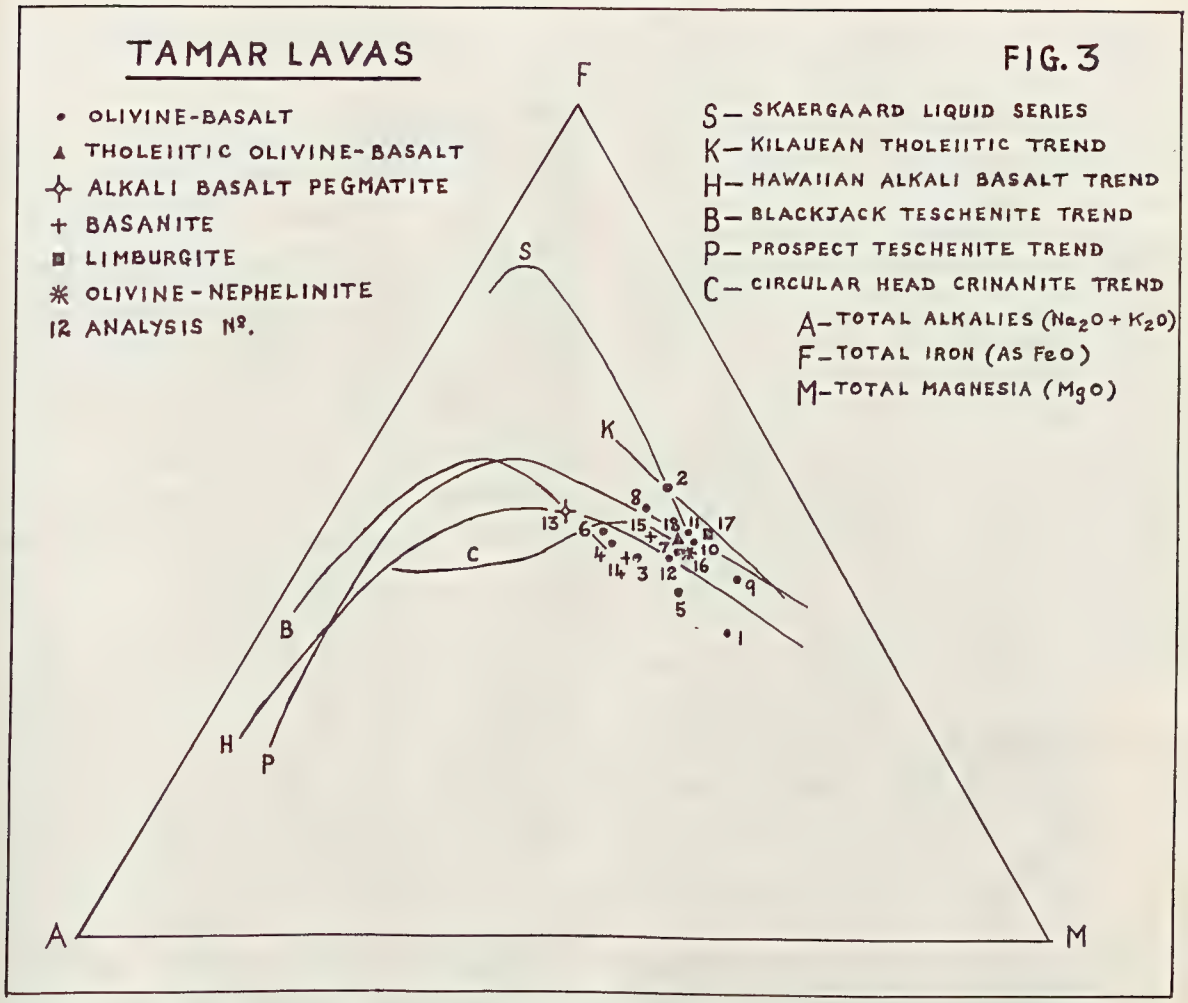

FIGURE 3—FMA ternary chemical variation diagram of the Tamar lavas; F, total iron as FeO; M, total magnesia as MgO; A, total alkalies as $Na_2O + K_2O$; S (trend of Skaergaard liquid series, Wager 1960); K (Killauean tholeiitic trend, Tilley 1960, Muir and Tilley 1963); H (Hawaiian alkali basalt trend, MacDonald 1949); B (Black Jack teschenite trend, Wilkinson 1958); P (Prospect teschenite trend, Wilshire 1967); C (Circular Head crinanite trend, from analyses of Edwards 1941).

Most of the Tamar lavas, if internal differentiation is discounted, fall in the field of slightly 'differentiated' rocks with solidification indices between 30 and 40. The nepheline-basanite (analysis 14) appears to be a slightly 'differentiated' variant of the undersaturated titan-augite olivine-basalts of the Tamar (analyses 7, 10 and 11, Table 1). The olivine-nephelinite (analysis 16, Table 1) with its solidification index of over 35 appears relatively little modified by differentiation, and the limburgite (analysis 17, Table 1), with its solidification index greater than the majority of the lavas, suggests an early derivative.

Variations in modal mineralogy, texture, chemical composition and solidification index in the coarse basalts of the Tamar suggest differentiation within the thicker parts of these flows (Plates 6, 7 and 8; analyses 4, 5, 6, 8 and 13, Table 1; Figure 4). This is most marked in the middle Tamar area and basalts were sampled here from four levels at East Arm for chemical analysis: from picritic basalt in the lower levels of a basalt fill at river level (analysis 5); from 150 feet above river level in the upper part of the fill, from olivine-poor, mesostasis-rich basalt (analysis 6); from basalt capping the hill at about 250 feet, adjacent to the fill (analysis 4), presumably representing less differentiated basalt; and from pegmatite at 350 feet (analysis 13), presumably representing a late-stage differentiate of the basalt capping. The analyses reflect the general modal compositions of the rocks; the picritic phase shows relative enrichment in magnesia

and ferrous iron and impoverishment in silica, alumina and ferric iron, compared with the basalt of the flow capping, and the mesostasis-rich and pegmatitic phases show relative enrichment in silica, alumina and ferric iron, and impoverishment in magnesia and ferrous iron. This differentiation trend is seen in the chemical variation diagrams (Figures 2, 3 and 4), and the solidification indices of the rocks spread from over 45 for the picritic phase to less than 25 for the pegmatitic phase, thus passing into the field of moderately strongly differentiated rocks. Coarse olivine-basalt from the upper part of the flow, south of Atkinsons Creek in the upper Tamar, also shows relatively low magnesia and high alumina and silica, suggesting some differentiation (analysis 8).

Differentiation and Behaviour of Titanium in the Clino-pyroxenes

Differentiation within the Tamar lavas has produced two trends of crystallisation of the pyroxenes in regard to the behaviour of titanium, often discriminated in alkali rocks (Yagi and Onamu, 1967); i.e., an initial trend of titanium enrichment in the earlier stages of fractionation, and a reverse trend of titanium depletion in the later stages of differentiation. Evidence of titanium enrichment in pyroxenes during early stages of fractionation is found in the following cases:—

(1) in the upper basalt in the lower Tamar and in the limburgite in the south Tamar, in which later stage pyroxenes crystallising in the mesostasis take on deepening coloration compared with the near colourless earlier groundmass pyroxene;

(2) in the undersaturated olivine-basalts and coarse olivine-basalts in which early pyroxenes with corrosion riddling are essentially colourless compared with coloured pyroxenes in the bulk of the rock;

(3) in the undersaturated olivine-basalts and coarse basalts, in which there is deepening of colours towards the outer zones of the pyroxene crystals, becoming particularly marked in the late-stage ophitic plates or in the presence of an abundant microlitic mesostasis;

(4) in the pyroxene-olivine-basalt from Corra Linn, in which the pyroxene overgrowths around the augite xenocrysts show a progressive change outwards from colourless to coloured augite.

Evidence of titanium depletion in pyroxenes during the later stages of fractionation in the Tamar rocks is found—

(1) in the late-stage pegmatitic veins and segregations in the coarse olivine-basalts and olivine-nephelinite, in which some of the titan-augites show paler coloured outer zones;

(2) in the coarse basalts in which titan-augite in contact with, or within the late-stage mesostasis is altered to greenish aegirine-augite, as these soda pyroxenes are generally poor in titanium relative to titan-augite (see Yagi and Onamu, 1967; Deer, Howie and Zussman, 1963: Tables 12 and 20).

Differentiation within Lavas

The available evidence suggests that the coarse basalts of the Tamar probably represent flows several hundred feet in thickness. Such thicknesses of lava would cool relatively slowly and seem adequate for differentiation to take place, based on known thicknesses of differentiated sills (200-700 feet thick) of similar rock composition elsewhere in Australia (Joplin, 1964). Differentiated sills such as the Prospect and Black Jack teschenite bodies in New South Wales (Wilshire, 1967; Wilkinson, 1958; Joplin, 1964) and the differentiated 'crinanite' in necks at Circular Head and Table Cape (Edwards, 1941; Gill and Banks, 1956; Gee, 1966), resemble the coarse basalts of the Tamar in many petrological features, although they show differences in details of differentiation.

The Circular Head and Prospect rocks crystallised from a parent magma of similar composition to that of the coarse basalt of the Tamar, but the Black Jack body crystallised from a slightly more alkaline magma, and all the differentiates are nepheline-normative, unlike some of the Prospect and Tamar rocks. The differentiation process in the sills and necks appears more pronounced than in the Tamar lavas, and the highly alkaline differentiates of these bodies, such as analcime-syenite and theralite were not noted in the Tamar rocks.

Differences in compositional trends of the mineralogical phases separating during crystallisation can be noted, as on comparing the olivines and clino-pyroxenes of the Black Jack and Tamar rocks. The late olivine in the Black Jack sill (Wilkinson, 1956a) shows greater iron enrichment than that in the late pegmatites of the coarse basalts of the Tamar, and this is presumed to reflect more lengthy cooling in a sill compared with a lava of comparable thickness. In the clino-pyroxenes of the Black Jack sill, Wilkinson (1957) notes an increase in reverse zoning with 2V margin $>$ 2V core as in the later titan-augite in the Tamar rocks. However, here, the increase appears to be due to the introduction of magnesium, and the titan-augites show decreased titanium contents, no significant increase in sodium content, and in contrast lack the extreme high values of $2V_z$ and Z:c shown by the Tamar titan-augites.

Comparison of the differentiation trends of the Black Jack, Prospect and Circular Head bodies plotted in the variation diagrams in Figures 2, 3 and 4, with that of the coarse basalt of the middle Tamar (analyses 4-6 and 13) reveals some interesting differences. The Tamar trend differs markedly from that of the Circular Head 'crinanite' trend, and although it again shows some differences, lies more closely to the femic extension of the Black Jack and Prospect trends. This suggests that the differentiation processes operating in thick flows of alkaline magma approach those shown by sills rather than necks.

Coarse olivine-basalt closely matching the Tamar basalts is also found in Tasmania at Mt Cameron West, apparently forming a single flow over 500

feet thick (Gill and Banks, 1956; Sutherland and Corbett, 1967). However, the rock at Mt Cameron West is not much differentiated and no marked pegmatitic or picritic phases were noted. This may have resulted from the lava here filling a narrower valley than in the Tamar and probably cooling more quickly relative to the process of differentiation. Thus, not only a sufficient depth, but also a sufficient width of lava, appears to be required for noticeable differentiation to take place in such flows.

The pegmatites of the Tamar basalts represent the extreme phase of the differentiation, with enrichment of silica, titania, soda and potash, at the expense of magnesia and lime. They occur mostly in the lower levels of the flows, showing that the parent residual fluids accumulated deep within the flows without wholesale migration into the upper levels; rocks with coarser ophitic textures and deeper coloured titan-augite are also found in the lower half of the Mt Cameron West flow. This behaviour contrasts with that normally found in differentiated sills, where the coarsest rocks and pegmatites tend to form in the upper levels, e.g., Black Jack, Prospect and Tasmanian Jurassic dolerite sills (Wilkinson, 1958; Wilshire, 1967; Joplin, 1964). This, no doubt, results from relatively more rapid chilling and crystallisation in the upper levels of flows, arising from a more unequal temperature gradient from top to bottom, compared with sills.

Fractionation trends of basalt magmas in lava flows are discussed by Kuno (1965) but his examples are drawn from tholeiites, high-alumina basalts and basaltic andesites rather than alkali basalts. Kuno considers that different trends in total iron and silica contents during differentiation arise largely from differences in oxygen partial pressure, probably due to differences in the initial water contents of the magma. The coarse basalt in the middle Tamar shows a typical alkali basalt trend of increasing silica and nearly constant total iron, which according to Kuno would indicate a high oxygen pressure and hence probably a high initial water content. The presence of abundant pegmatites and mesostasis-rich phases in the basalt, carrying hydrous minerals such as analcime, other zeolites, biotite and chlorite fully supports this.

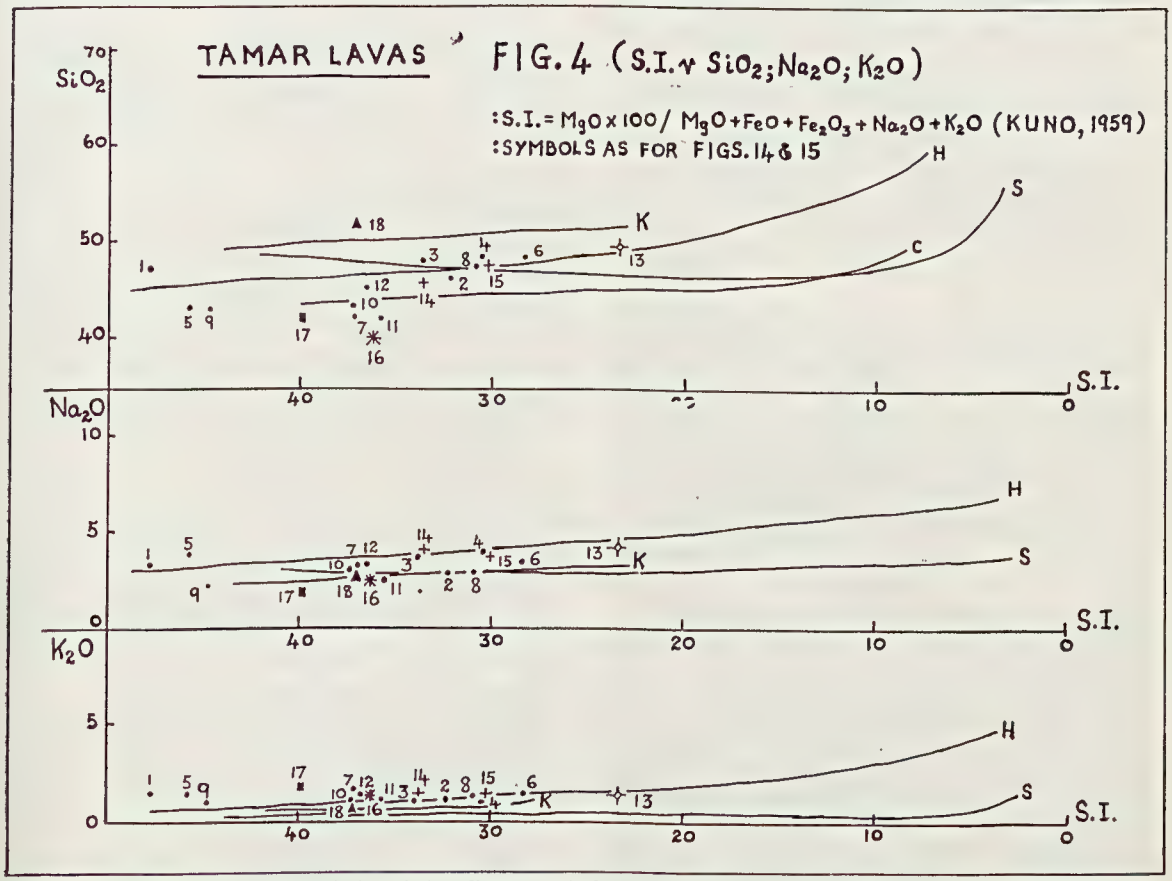

FIGURE 4—Solidification index chemical variation diagrams of the Tamar lavas: S.I. (solidification index, Kuno 1959) v SiO_2, Na_2O, K_2O; S (trend of Skaergaard liquid series, Wager 1960); K (Kilauean tholeiitic trend, Tilley 1960, Muir and Tilley 1963); H (Hawaiian alkali basalt trend, MacDonald 1949); C (Circular Head crinanite trend, from analyses of Edwards 1941) N.B.—The reference to Figs. 14 and 15 in Fig. 4 should read as Figs. 2 and 3.

PETROCHEMICAL AFFINITIES OF THE TAMAR LAVAS

The Tertiary volcanic rocks of the Tamar Trough range from undersaturated lavas such as olivine-nephelinite, nepheline-basanite and limburgite through undersaturated and near-saturated olivine-basalts to saturated olivine-basalt. The bulk of the lavas are undersaturated to near-saturated olivine-basalts, with the other rocks only forming small restricted flows. In general, the Tamar suite can be regarded as predominantly an alkaline association, with minor tholeiitic lava, as discussed later. In this study the petrochemical affinities of the Tamar lavas are examined in relation to similar Cainozoic volcanic associations in the Australasian region and then compared with a few of the well-known petrographic suites elsewhere in the world.

Australasian Affinities

Alkaline volcanic suites similar to the Tamar lavas are found elsewhere in Tasmania (Edwards, 1950; Spry, 1962; Sutherland, 1969a, 1969b); in eastern Australia, best typified by the Older Volcanic series of Victoria (Edwards, 1939, 1950); and in New Zealand, best typified by the Auckland Basalts (Searle, 1961). The available petrochemical data on the Tasmanian Cainozoic volcanic province (including that of the Tamar suite) is discussed by Sutherland (1969b) and a further analysis is not attempted here. Detailed petrochemical data are scanty for the Older Volcanic series of Victoria, but the average calculated basalt (Edwards, 1939) compares closely with that of the Tamar suite (analysis 12, Table 1). Detailed petrochemical data has been presented for the Auckland Basalts (Searle, 1961), enabling a close comparison with the Tamar suite.

The Tamar alkali basalts (analyses 1 to 11, Table 1) chemically resemble the Auckland basalts in degree of silica undersaturation, in relatively high alkali contents, and in alumina contents mostly in excess of magnesia and present in approximately sub-equal amounts with lime and ferrous oxide. The average calculated composition of the Tamar basalts (analysis 12, Table 1) is very close to that of the average Auckland basalt and indicates a similar parent magma, chemically intermediate between the 'normal alkaline basalt' and the 'olivine-rich alkaline basalt' of Nockolds (1954). The Tamar basalts, however, tend to be somewhat richer in iron oxide at the expense of magnesia, and this is probably reflected in the relatively more common occurrence of picrite basalts amongst the Auckland lavas.

Norms calculated for the Tamar basalts (Table 1) resemble those of the Auckland basalts in that some of the rocks show noticeable amounts of normative nepheline, which finds little or no modal expression. In the Auckland rocks the excess soda is apparently incorporated into the residual groundmass feldspar and mesostasis. The Tamar basalts show a similar behaviour, although in the coarser basalts the excess soda appears as analcime. Further, the presence of titaniferous augites in the rocks will increase the available silica by substitution (probably Ti for Mg. accompanied by Al for Si; see Yagi and Onamu, 1967), and in reality diminish the apparent values of normative nepheline. Some of the Tamar basalts also contain aegirine-augite and sodian titan-augites (judging from their optical properties as previously discussed), and this would also use some of the available soda.

Some of the Tamar basalts approach basanites in regard to their chemistry and calculated normative nepheline, but mineralogically they are olivine-basalts grading to analcime bearing olivine-basalts. Rocks termed basanites in the Tamar suite and elsewhere in Tasmania, and on mainland Australia, generally show slightly greater alkali contents (analysis 14, Table 1; Spry, 1962, analyses 108-109; Joplin, 1963, Tables N and O), as does the average teschenite (and corresponding lavas) of Nockolds (1954). Of particular interest in this respect is the nepheline-basanite at Deviot, with about 8% modal nepheline, which grades into an analcime bearing coarse olivine-basalt, with only a slight decrease in alkalies and a slight increase in silica (analysis 15, Table 1). This indicates strong sensitivity between the chemistry and mineralogy in these rocks.

The general lack of modal nepheline in basalts in the presence of high normative nepheline is typical of the rocks belonging to the alkali-rich, sub-aluminous associations of the Pacific Basin (Barth, 1931). The alkali and calcic contents of the Tamar rocks, with the field of the Auckland Basalts for comparison, are plotted on a ternary diagram (Figure 1) similar to that used by Searle (1960), after Green and Poldervaart (1958). The diagram plots the relative number of ions of K-Na-Ca (data from Table 1) and illustrates the close affinities of the Tamar and Auckland suites, and the distribution relative to the trend lines recognised by Green and Poldervaart. The Tamar suite, as does the Auckland suite, lies along trend B, and thus, although chemically comparable with the lavas from the sub-aluminous alkaline associations of the Pacific Basin, is possibly derived by fractionation along a trend more characteristic of a continental environment (Searle, 1960).

Relationships to Some Overseas Petrographic Provinces

The petrochemistry of the Tamar suite (analyses 1-18, Table 1) is plotted on a number of variation diagrams (Figures 2, 3, and 4) and compared with trend lines of the well known Skaergaard liquid series (Wager, 1960), the Kilauean tholeiitic rocks (Tilley, 1960; Muir and Tilley, 1963) and the Hawaiian alkali basalts (MacDonald, 1949).

In the diagram for alumina against total alkalies (Figure 2a), with basalt field boundaries from Kuno (1960) for SiO_2 45.00-47.50, the Tamar suite plots from the tholeiitic field into the alkali basalt field. with no plots in the high-alumina basalt field. The tholeiitic olivine-basalt from 7EX Hill (analysis 18) occupies a position between the two fields, but would fall in the tholeiite field using the appropriate SiO_2 50.01-52.50 boundary of Kuno. In the FMA diagram (Figure 3) it falls between the Kilauean tholeiite and Hawaiian alkali basalt trends, near the Skaergaard trend. However, in the diagram for silica against total alkalies (Figure

2b) it clearly falls within the tholeiite field of MacDonald and Katsura (1964), and in the diagrams for SiO_2 against FeO + Fe_2O_3/MgO + FeO + Fe_2O_3 (Figure 2d), for MgO against Al_2O_3/SiO_2 (Figure 2c) after Murata (1960), and for Kuno's (1959) solidification index against SiO_2, Na_2O and K_2O (Figure 4) it is associated with the Kilauean tholeiitic trend.

The limburgite from 'Duneiden Farm' (analysis 17) plots with the alkali basalts in a number of the variation diagrams, but in the FMA diagram (Figure 3) it plots on the Kilauean tholeiitic trend. In the diagram for alumina against total alkalies (Figure 2a) it again plots in the tholeiite field, although allowance for its undersaturated composition to the SiO_2 45.00-47.50 boundary of Kuno (1960) must be made. This suggests that the limburgite may be derived from a tholeiitic olivine-basalt parent, a possibility strengthened by its close field association with the 7EX Hill tholeiitic olivine-basalt.

The alkali olivine-basalts of the Tamar, as plotting in the diagram for silica against total alkalies (Figure 2b), form a suite of mildly alkaline basalts overlapping into the field of strongly alkaline basalts, relative to the boundary after Saggerson and Williams (1964). In the variation diagrams they plot near the Hawaiian alkali basalt trend, with two main exceptions. In the diagram for alumina against total alkalies (Figure 2a) the pyroxene-olivine-basalt from Corra Linn (analysis 9) plots in the tholeiite field, but this is due to the numerous xenocrysts of aluminous augite in the rock, reducing the relative alumina and alkali content, and to its undersaturated composition in respect to the SiO_2 45.00-47.50 boundary of Kuno (1960). Again, the upper olivine-basalt from the lower Tamar area (analysis 2), although plotting as an alkali basalt in Figures 2b, 2d and 4, plots on the Kilauean tholeiite trends in Figures 2c and 3, due to its relatively high iron content.

The alkaline rocks represented by the more differentiated phases and the pegmatite of the coarse olivine-basalts (analyses 4, 6, 8 and 13), and the nepheline-basanite from Deviot (analyses 14 and 15), tend to plot as an extension of the olivine-basalts along the trend of the Hawaiian alkali basalts. Overall, the variation diagrams indicate that the Tamar alkali basalt trend approaches that of the Hawaiian basalts, with the Tamar rocks tending to be enriched in alkalies and impoverished in magnesia in respect to silica (Figures 2b, 2d). Thus, in the FMA diagram (Figure 3), the differentiated alkaline-rich, analcime bearing, coarse basalt from the middle Tamar (analyses 4, 5, 6 and 13) plots towards the extension of the Black Jack teschenite trend of Wilkinson (1958). The olivine-nephelinite from Spring Bay (analysis 16) plots away from the Tamar and Hawaiian alkali basalt trends in some of the variation diagrams (Figures 2b, 2d and 4), a point discussed later.

THE ERUPTIVE AND MAGMATIC HISTORY OF THE TAMAR LAVAS

The Eruptive Succession

The Tamar extrusions have been dated to a limited extent from the field stratigraphy, but precise datings will require detailed radiometric and palaeomagnetic studies.

From presently available evidence the eruptive sequence tentatively suggested for the Tamar volcanism is: initial eruptions of near-saturated alkali olivine-basalts in the lower and south Tamar areas during the Lower Tertiary, probably post-Middle Eocene and pre-Upper Oligocene; then extrusion of olivine-nephelinite in the middle Tamar area in the Lower to Middle Tertiary, probably in the Oligocene; and finally effusions of undersaturated alkali olivine-basalts and nepheline-basanite, followed by thick coarse alkali olivine-basalts in the middle, upper and south Tamar areas in Middle or Upper Tertiary time, probably post-Upper Oligocene and pre-Middle Pliocene. The positions in this sequence of the small extrusions of olivine-nephelinite, tholeiitic olivine-basalt and limburgite in the south Tamar are unknown.

Genesis of the Tamar Lavas

The Tamar lavas form essentially an alkaline suite, apparently derived from alkali basalt parent magmas. Recent work on genesis of basalts (Green and Ringwood, 1967) suggest that such parent magmas may be generated by relatively restricted degrees of direct partial mantle melting, with segregation of the alkali basalt magmas at depths of 35-70 Kms.

The initial magma appears to have ascended in a fairly undifferentiated state to form the lower olivine-basalt in the lower Tamar (solidification index $>$ 45, Figure 4), but then underwent some differentiation prior to further eruption to form the upper olivine-basalt (solidification indices $<$ 35 $>$ 30).

The next phase appears as minor extrusion of olivine-nephelinite in the middle Tamar, and possibly in the south Tamar. This may represent more extreme differentiation of the initial alkali-basalt magma, but its relatively high solidification index, and its tendency to plot away from the alkali basalt trend in variation diagrams, infers a somewhat different origin. Recent work by Bultitude and Green (1968) suggests that such rocks may form during waning in volcanism under a low degree of melting, giving more hydrous conditions that allow fractionation of alkali basalt magma towards such undersaturated compositions at depths of 60-100 Kms.

This was followed by the eruption of undersaturated olivine-basalts in the upper and south Tamar, presumably following renewed, more widespread generation and segregation of alkali basalt magma at depths of 35-70 Kms. These basalts approach basanites in composition and show solidification indices between 45-35. The augite xenocrysts in the Corra Linn basalt suggests that magma may have formed by fractional crystallisation of this augite from a more primitive parent. Crystallisation of augite of such composition points to a parent magma richer in silica, lime and magnesia and somewhat poorer in iron, alumina and alkalies, but rocks of such composition are unknown in the Tamar suite. Alternatively, however, if fractionation proceeded by crystallisation of olivine and/or spinel, as well as augite, then this provides

for relatively constant compositions in regard to lime and would give a parent magma approaching the composition of the lower olivine-basalt in the lower Tamar, but a little poorer in alkalies. Whether the olivine-augite nodules found in the rocks represent products of such fractionation is uncertain without more detailed work.

The final phase of the volcanism includes the extrusion of the coarse olivine-basalts in the middle, upper and south Tamar areas and possibly the nepheline-basanite in the middle Tamar. These lavas tend to show slight enrichment in silica, alkalies and alumina compared with the preceding undersaturated olivine-basalts. This may reflect some differentiation within the undersaturated magma at relatively higher levels and lower pressures, as low pressure differentiation along similar trends continued within the thick lavas after extrusion.

The tholeiitic olivine-basalt, and possibly the alkali-poor limburgite, in the south Tamar area form the western outskirts of a tholeiitic olivine-basalt association to the south-east and east, overlapping into the alkaline suite of the Tamar Trough. Following the studies of Green and Ringwood (1967), the parent tholeiitic magmas for this association may have formed as the result of relatively higher degrees of partial mantle melting, with segregation of magma at depths of 35-70 Kms. In the broad context, the Tamar Trough falls within an alkaline volcanic association extending to the west as far as the Devonport-Deloraine area (interpreted as possibly representing an area of lesser mantle melting), but its south-eastern end passes transitionally into a dominantly tholeiitic association extending to the east as far as the Camden Plains-Avoca area (interpreted as possibly representing an area of greater mantle melting). The overall aspects of the Cainozoic volcanism of the Tasmanian province, including that of the Tamar Trough, are reviewed elsewhere (Sutherland, 1969b).

TABLE 1

Chemical Analyses and Molecular Norms—Tamar Tertiary Lavas

Analysis	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
SiO_2	47.04	46.3	47.93	47.21	43.12	48.40	42.3	47.5	43.0	43.2	42.2	45.18	49.53	45.95	47.48	40.0	42.0	51.52
Al_2O_3 ..	12.05	12.0	15.28	14.26	13.07	15.49	13.9	14.7	13.6	14.0	12.9	13.75	14.34	13.05	13.49	12.2	11.4	13.76
Fe_2O_3.. ..	0.31	3.7	1.43	1.01	0.93	3.61	4.3	2.8	4.1	4.4	4.7	2.84	2.84	1.53	2.15	3.9	4.0	1.43
FeO	9.98	11.6	8.78	9.33	10.83	6.67	9.2	9.8	8.0	9.2	10.0	9.40	8.76	10.29	10.45	10.7	10.4	8.78
MnO	0.24	0.20	0.19	0.15	0.13	0.21	0.1	0.20	0.17	0.1	0.22	0.17	0.18	0.24	0.19	0.24	0.2	0.18
TiO_2	1.82	2.2	2.00	2.15	2.53	2.25	2.3	1.6	2.3	2.3	2.2	2.15	3.21	2.42	2.37	2.8	2.5	1.78
P_2O_5	0.53	0.59	0.83	0.42	0.44	0.44	1.53	0.51	0.62	0.79	0.86	0.69	0.62	0.98	0.42	1.2	0.83	0.18
CaO	8.34	8.2	10.00	9.26	9.67	9.69	10.9	9.5	11.2	11.1	9.3	9.74	8.41	10.02	8.07	9.4	11.3	8.46
MgO	13.59	9.1	7.60	6.64	11.46	5.89	10.7	7.4	12.4	10.5	10.5	9.62	5.27	8.58	8.76	11.2	11.7	7.95
Na_2O	3.20	2.8	3.54	3.77	3.83	3.37	3.06	2.7	2.2	3.03	2.5	3.09	4.05	4.11	3.61	3.6	1.8	2.65
K_2O	1.41	1.0	1.15	1.09	1.44	1.27	1.56	1.3	1.0	1.07	1.6	1.26	1.56	1.18	1.11	1.5	1.6	0.64
Ignition Loss	2.13	1.3	1.45	3.52	1.57	1.59	1.05	1.5	0.94	0.80	1.7	1.59	1.45	2.05	2.80	2.0	1.12	1.69
H_2O^- ..	0.65	0.71	0.64	0.40	0.16	0.34	0.10	0.67	0.84	0.16	1.1	0.52	0.64	0.48	0.57	0.89	0.40	0.15
Total ..	101.29	99.70	100.82	99.21	99.42	99.22	100.90	100.18	100.37	100.65	99.78	100.00	100.86	100.88	101.47	99.63	99.25	99.17

TABLE 1—*Chemical Analysis and Molecular Norms—Tamar Tertiary Lavas—contd.*

C.I.P.W. Norm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Q	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.25
Or	8.33	5.91	6.80	6.44	8.51	7.51	9.22	7.68	5.91	6.32	9.46	7.45	9.22	6.97	6.56	8.87	9.46	3.78
Ab	17.34	23.69	25.17	25.73	4.45	28.52	8.32	22.85	9.98	10.31	12.30	17.87	34.27	18.24	27.49	4.80	5.55	22.42
An	14.35	17.22	22.41	18.77	14.22	23.39	19.59	24.15	24.28	21.44	19.25	19.93	16.34	13.68	17.33	12.70	18.30	23.76
Ne	5.28	0.00	2.59	3.34	15.15	0.00	9.52	0.00	4.68	8.30	4.80	4.48	0.00	8.96	1.66	13.90	5.24	0.00
Di	*19.03*	*16.00*	*17.76*	*20.05*	*25.05*	*17.56*	*19.67*	*16.09*	*21.70*	*22.87*	*17.15*	*19.33*	*17.42*	*24.19*	*16.28*	*21.05*	*26.05*	*13.88*
En ..	6.30	4.71	5.30	5.51	7.93	6.02	6.92	4.56	8.24	8.02	5.78	6.29	5.10	7.12	4.86	7.06	8.88	4.17
Fs ..	2.89	3.11	3.36	4.34	4.22	2.44	2.53	3.32	2.09	2.96	2.49	3.07	3.41	4.69	3.09	3.10	3.67	2.60
Wt ..	9.84	8.19	9.09	10.20	12.89	9.11	10.23	8.20	11.37	11.89	8.88	9.97	8.91	12.38	8.34	10.90	13.50	7.11
Hy	*0.00*	*8.13*	*0.00*	*0.00*	*0.00*	*3.68*	*0.00*	*5.40*	*0.00*	*0.00*	*0.00*	*0.00*	*0.39*	*0.00*	*0.00*	*0.00*	*0.00*	*25.37*
Et ..	0.00	4.90	0.00	0.00	0.00	2.62	0.00	3.12	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.00	0.00	15.66
Ft ..	0.00	3.22	0.00	0.00	0.00	1.06	0.00	2.27	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00	9.70
Ol	*29.05*	*15.28*	*16.21*	*14.43*	*22.91*	*6.11*	*19.39*	*13.57*	*20.29*	*17.87*	*21.04*	*19.04*	*9.48*	*17.23*	*20.20*	*21.67*	*20.67*	*0.00*
Fo ..	19.30	9.15	9.55	7.73	14.44	4.23	13.83	7.53	15.87	12.70	14.27	12.38	5.46	9.98	11.88	14.60	14.20	0.00
Fa ..	9.75	6.67	6.67	6.71	8.47	1.89	5.56	6.04	4.43	5.17	6.77	6.65	4.02	7.25	8.32	7.07	6.46	0.00
Mt	0.45	5.37	2.07	1.46	1.35	5.23	6.24	4.06	5.95	6.38	6.82	4.12	4.12	2.22	3.12	5.66	5.80	2.07
Il	3.46	4.18	3.80	4.08	4.81	4.27	4.37	3.04	4.37	4.37	4.18	4.08	6.10	4.60	4.50	5.32	4.75	3.38
Ap	1.26	1.40	1.97	1.00	1.04	1.04	3.62	1.21	1.47	1.87	2.04	1.63	1.47	2.32	1.00	2.84	1.97	0.43
$H_2O\pm$ ..	2.78	2.01	2.09	3.92	1.73	1.93	1.15	2.17	1.78	0.96	2.80	2.11	2.09	2.53	3.33	2.89	1.52	1.84
Total ..	101.33	99.73	100.87	99.22	99.22	99.24	101.09	100.22	100.41	100.69	99.84	100.04	100.90	100.94	101.47	99.70	99.31	99.18

TABLE 1—*Chemical Analysis and Molecular Norms—Tamar Tertiary Lavas—contd.*

Cation/Unit Cell. Oxygen	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Si	29.53	28.61	29.04	28.66	26.94	29.14	26.36	28.98	26.57	26.88	26.36	27.79	30.01	28.34	29.02	25.28	26.42	31.00
Ti	0.86	1.02	0.91	0.98	1.19	1.02	1.08	0.73	1.07	1.08	1.03	1.00	1.46	1.12	1.09	1.33	1.18	0.81
Al	8.92	8.74	10.91	10.20	9.62	10.99	10.21	10.57	9.91	10.27	9.50	9.97	10.24	9.49	9.72	9.09	8.45	9.76
Fe^{+++} ..	0.14	1.72	0.65	0.46	0.44	1.64	2.02	1.29	1.91	2.06	2.21	1.32	1.30	0.71	0.99	1.86	1.89	0.65
Fe^{++}	5.24	5.99	4.45	4.74	5.66	3.36	4.79	5.00	4.14	4.79	5.22	4.84	4.44	5.31	5.34	5.66	5.47	4.42
Mn	0.13	0.11	0.09	0.08	0.07	0.11	0.05	0.10	0.09	0.05	0.12	0.09	0.09	0.13	0.10	0.13	0.11	0.09
Mg	12.72	8.38	6.86	6.01	10.67	5.29	9.94	6.73	11.42	9.74	9.78	8.82	4.76	7.89	7.98	10.55	10.97	7.13
Ca	5.61	5.43	6.49	6.02	6.47	6.25	7.28	6.21	7.42	7.40	6.23	6.42	5.46	6.62	5.29	6.37	7.62	5.45
Na	3.90	3.35	4.16	4.44	4.64	3.94	3.70	3.19	2.64	3.66	3.03	3.69	4.76	4.91	4.28	4.41	2.20	3.09
K	1.13	0.79	0.89	0.84	1.44	0.98	1.24	1.01	0.79	0.85	1.28	0.99	1.21	0.93	0.87	1.21	1.28	0.49
P	0.28	0.31	0.43	0.22	0.23	0.22	0.81	0.26	0.32	0.42	0.46	0.36	0.32	0.51	0.22	0.64	0.44	0.09

1. Olivine-basalt. Lower flow, east end of Greens Beach, Tamar Heads.
2. Olivine-basalt. Upper flow, above road cut, 70 ft level, Inspection Head, West Tamar.
3. Porphyritic olivine-basalt. West bank of East Arm, above 200 ft level, 1 mile NW. of Fourteen Mile Creek, East Tamar.
4. Coarse olivine-basalt. West bank of East Arm, H.E.C. pylon, 225 ft level, 1 mile NW. of Fourteen Mile Creek, East Tamar.
5. Coarse olivine-basalt. Picritic phase, west shore of East Arm, ¾ mile NW. of Fourteen Mile Creek, East Tamar.
6. Coarse olivine-basalt. Mesostasis rich-phase, west bank of East Arm, 150 ft level, ¾ mile NW. of Fourteen Mile Creek, East Tamar.
7. Olivine-basalt. Upper West Tamar Highway, ¾ mile N. of Muddy Creek.
8. Coarse olivine-basalt. Scarp top, above West Tamar Highway, S. of Atkinsons Creek, 1 mile due S. of Rosevears.
9. Pyroxene-olivine-basalt. North Esk, 1¼ miles N. of Corra Linn.
10. Olivine-basalt. Quarry, above 'Talisker' Farm, Rose Rivulet.
11. Olivine-basalt. 1½ miles SE. of White Hills.
12. Average alkali olivine-basalt. Tamar Trough (average of analyses 1-11).
13. Pegmatite. In coarse olivine-basalt, plateau, 1½ miles N. of Craigburn, East Tamar.
14. Nepheline-basanite. Fine grained phase, Deviot shore, West Tamar.
15. Nepheline-basanite. Coarse olivine-basalt phase, Deviot shore, West Tamar.
16. Olivine-nephelinite. East Arm Road–Batman Bridge Road Junction, N. of Spring Bay, East Tamar.
17. Limburgite. 'Dunciden' Farm, 2 miles ESE. of St Leonards.
18. Tholeiitic olivine-basalt. 7EX Hill, St Leonards.

Analyses 1, 3-6, 13-15, and 18, by X-ray fluorescence, with Na_2O and K_2O by flame photometry, and FeO by titration using the method of Reichen and Fahey (1962): F. L. Sutherland, analyst.
Analyses 7, 10, and 17, mainly by X-ray fluorescence, with Na_2O and K_2O by flame photometry: D.I. Groves and G. Sanders, analysts.
Analyses 2, 8, 9, 11 and 16, by Tasmanian Mines Department Laboratories, Launceston: J. Furst, analyst.

TABLE 2

Analyses of Pyroxenes and Spinel from pyroxene-olivine-basalt, Corra Linn and Blessington

Analysis	1 Augite-xenocryst core	2 Augite-xenocryst core	3 Augite-in reaction rim	4 Augite-new over-growth	5 Spinel xenocryst	6 Clino-pyrox-ene-peridotite nodule
SiO_2	48.8	48.8	49.4	48.8	..	52.9
TiO_2	0.6	0.8	0.8	1.3	0.7	0.3
Al_2O_3 ..	9.2	10.2	6.9	6.6	64.9	7.3
Total FeO ..	5.7	6.4	6.2	6.8	16.4	2.0
MnO ..	0.4	0.4	0.4	0.4	..	0.2
MgO ..	17.0	15.0	16.1	14.6	18.4	16.6
CaO	17.9	18.4	19.6	20.2	..	19.0
Na_2O ..	0.9	1.0	0.4	0.4	..	1.4
K_2O	<0.01	<0.01	<0.03	<0.01	..	<0.01
Cr_2O_3 ..	..	..	..	..	0.2	..
Total ..	100.5	101.0	99.8	99.1	100.6	99.7

Microprobe analyses by courtesy of N. Gray and D. H. Green, Australian National University.
Analyses 1-5 from Corra Linn basalt, analysis 6 from Blessington basalt.

REFERENCES

BARTH, T. W. F., 1931—Mineralogical Petrography of Pacific Lavas. *Amer. J. Sci.* 125, pp. 377-405. *Ibid.*, 126, pp. 491-530.

BLACK, P. M., and BROTHERS, R. N., 1965—Olivine Nodules from Tokatoka, Northland. *N.Z.J. Geol. Geophys.*, 8, 1, pp. 62-80.

BROTHERS, R. N., 1960—Olivine Nodules from New Zealand. *Rep. 21st Int. Geol. Cong.*, 13, pp. 68-81.

BULTITUDE, R. J., and GREEN, D. H., 1968.—Experimental Study at High Presures on the Origin of Olivine Nephelinite and Olivine Melilite Nephelinite Magmas. *Earth Planet Sci. Letters*, 3, 4, pp. 325-337.

DEER, W. A., HOWIE, R. A., and ZUSSMAN, J., 1963—Rock Forming Minerals *Chain Silicates*. Vol. 2. Longmans, London.

EDWARDS, A. B., 1939—Petrology of the Tertiary Older Volcanic Rocks of Victoria. *Proc. Roy. Soc. Vict.* 51, 1, pp. 73-98.

———, 1941—The Crinanite Laccolith of Circular Head, Tasmania. *Proc. Roy. Soc. Vict.*, 53, 2 (N.S.) pp. 403-415.

EDWARDS, A. B., 1950—The Petrology of the Cainozoic Basaltic Rocks of Tasmania. *Proc. Roy. Soc. Vict.*, 62, 1 (N.S.) pp. 97-120.

EMMONS, R. C., 1943—The Universal Stage. *Geol. Soc. Amer. Mem.* 8.

GEE, D., 1966—Table Cape Map Sheet. *Geol. Surv. Tasm.* 1-Mile Geol. Map Ser. No. 22.

GILL, E. D., and BANKS, M. R., 1956—Cainozoic History of the Mowbray Swamp and Other Areas of North-Western Tasmania. *Rec. Q. Vict. Mus.* N.S. 6.

GREEN, D. H. and RINGWOOD, A E., 1967—The Genesis of Basaltic Magmas. *Contr. Mineral and Petrol.*, 15, pp. 103-190.

GREEN, J., and POLDERVAART, A., 1958—Petrochemical Fields and Trends. *Geochim et Cosmoch Acta.*, 13, pp. 87-122.

JOPLIN, G. A., 1963—Chemical Analyses of Australian Rocks. Pt. 1: Igneous and Metamorphic *Bull. Bur. Min. Resour. Aust.* 65.

———, 1964—'A Petrography of Australian Igneous Rocks'. Angus and Robertson, Sydney.

KUNO, H., 1959—Origin of Cenozoic petrographic provinces of Japan and surrounding areas. *Bull. Volcan.* Ser. 2, 20, pp. 37-76.

————, 1960—High Alumina basalt. *J. Petrology* 1, pp. 121-145.

————, 1965—Fractionation Trends of Basalt Magmas in Lava Flows. *J. Petrology* 6, 2, pp. 302-321.

LONGMAN, M. J., 1966—Launceston *Explan. Rep. Geol. Surv.* Tas. 1-Mile Geol. Map. Ser. K'55-7-39.

MACDONALD, G. A., 1949—Hawaiian petrographic province. *Bull. Geol. Soc. Amer.*, 60, pp. 1541-1596.

————, and KATSURA, T., 1964—Chemical Composition of Hawaiian lavas. *J. Petrology* 5, pp. 82-133.

MUIR, E. D., and TILLEY, C. E., 1963—Contributions to the Petrology of the Hawaiian Basalts; II The Tholeiitic Basalts of Mauno Loa and Kilauea. *Amer. J. Sci.* 261, pp. 111-128.

MUNRO, M., 1966—The measurement of large optic axial angles with the Universal stage. *Min. Mag.* 35, pp. 763-769.

MURATA, K. J., 1960—A new method of plotting chemical analyses of basaltic rocks. *Amer. J. Sci.* 258A, pp. 247-252.

NOCKOLDS, S. R., 1954—Average Chemical Compositions of some Igneous Rocks. *Bull. Geol. Soc. Amer* 65, pp. 1007-1032.

REICHEN, L. A., and FAHEY, S., 1962—An Improved Method for the Determination of FeO in Rocks and Minerals, including Garnet. *U.S. Geol. Surv. Bull.* 144B.

RITTMANN, A., and EL-HINNAWI, E. E., 1961—The Application of the Zonal Method for the Distinction between Low- and High-Temperature Plagioclase Feldspars. *Schweiz. Miner. Petrogr. Mitt.*, 41, pp. 41-48.

SAGGERSON, E. P., and WILLIAMS, L. A. J., 1964—Ngurumanite from Southern Kenya and its Bearing on the Origin of Rocks in the Northern Tanganyika Alkaline District. *J. Petrology* 5, pp. 40-81.

SEARLE, E. J., 1960—Petrochemistry of the Auckland Basalts. *N.Z.J. Geol. Geophys.*, 3, 1, pp. 23-40.

————, 1961—The Petrology of the Auckland Basalts. *N.Z.J. Geol. Geophys.*, 4, 2, pp. 165-204.

————, 1962—Quartzose Xenoliths and Pyroxene Aggregates in the Auckland Basalts. *N.Z. J. Geol. Geophys.*, 5, 1, pp. 130-140.

SPRY, A. H., 1962—Igneous Activity in 'The Geology of Tasmania'. *J. Geol. Soc. Aust.*, 9, 2, pp. 255-284.

SUTHERLAND, F. L., 1966—The Tertiary Volcanics of the Tamar Valley, Northern Tasmania—A Preliminary Report. *Aust. J. Sci.*, 29, 4, pp. 114-115.

————, 1969a—A Comparison of the Cainozoic Volcanic Provinces of Victoria and Tasmania. *Proc. Roy. Sci. Vict. (in press)* 82, 2 (N.S.).

SUTHERLAND, F. L., 1969b—A Review of the Tasmanian Cainozoic Volcanic Province. *Palaeovolcanology Symposium, Geol. Soc. Aust. (in press).*

————, and CORBETT, K. D., 1967—The Tertiary Volcanic Rocks of the Far North-West Tasmania. *Proc. Roy. Soc. Tasm.*, 101, pp. 71-90.

TILLEY C. E., 1960—Differentiation of Hawaiian Basalts: Some Variants in Lava Suites of Dated Kilauean Eruptions. *J. Petrology* 1, pp. 47-55.

TURNER, F. J. and VERHOOGEN, J., 1951—'Igneous and Metamorphic Petrology'. McGraw Hill Book Co. Inc., N.Y.

WAGER, L. R., 1960—The Major Element Variation of the Layered Series of the Skaergaard Intrusion and a Re-estimation of the Average Composition of the Hidden Layered Series and of the Successive Residual Magmas. *J. Petrology* 1, pp. 364-498.

————, 1962—Igneous Cumulates from the 1902 Eruption of Soufrier, St Vincent *Bull. Vulcan.* 24, pp. 93-99.

WILKINSON, J. F. G., 1956a—The Olivines of a Differentiated Teschenite Sill near Gunnedah, New South Wales. *Geol. Mag.* 93, pp 414-455

———— 1956b—Clinopyroxenes of Alkali Olivine-Basalt Magma. *Amer. Min.* 41, pp. 724-743.

————, 1957—The Clinopyroxenes of a differentiated teschenite sill near Gunnedah, New South Wales. *Geol. Mag.* 94, pp. 123-134.

————, 1958—The Petrology of a differentiated teschenite sill near Gunnedah, New South Wales. *Amer. J. Sci.* 256, pp. 1-39.

WILSHIRE, H. G., 1967—The Prospect Alkaline Diabase—Picrite Intrusion. N.S.W. Australia. *J. Petrology* 8, pp. 97-163.

————, and BINNS, R A., 1961—Basic and Ultrabasic Xenoliths from Volcanic Rocks of N.S.W. *J. Petrology* 2, pp. 185-208.

WYLLIE, P. J., 1959—Discrepancies between optic axial angles of olivines over different bisectrices. *Amer. Min.* 44, p. 49.

YAGI, K., 1953—Petrochemical studies of the alkalic rocks of the Morotu District, Sakhalin. *Bull. Geol. Soc. Amer.* 64, pp. 769-809.

————, and ONUMA, K., 1967—The Join $CaMgSi_2O_6$ $CaTiAl_2O_6$ and its Bearing on the Titan Augites. *J. Fac. Sci. Hokkaido Univ. Ser. IV. Geol. & Min.* XIII, 4, pp. 463-483.

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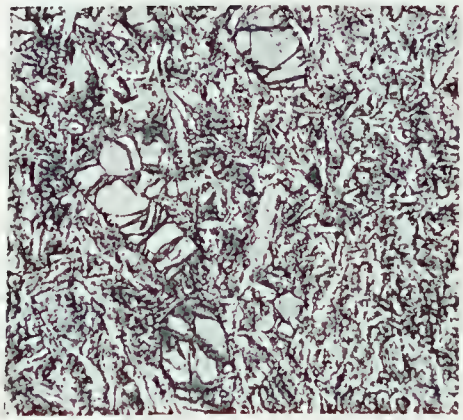
(All photomicrographs taken with uncrossed nicols. T.S. numbers refer to Tasmanian Museum thin section catalogue numbers)



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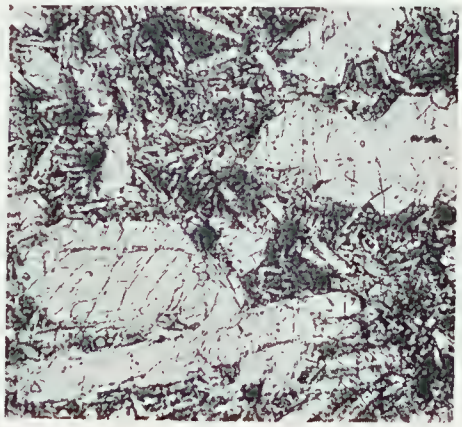

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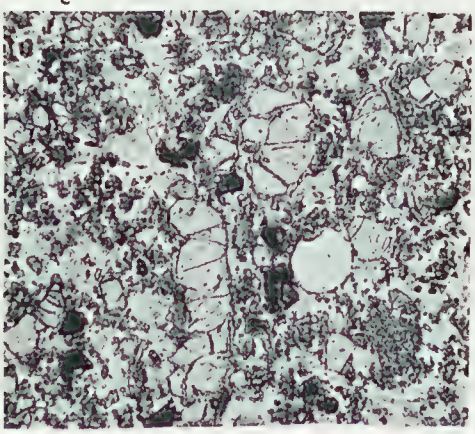

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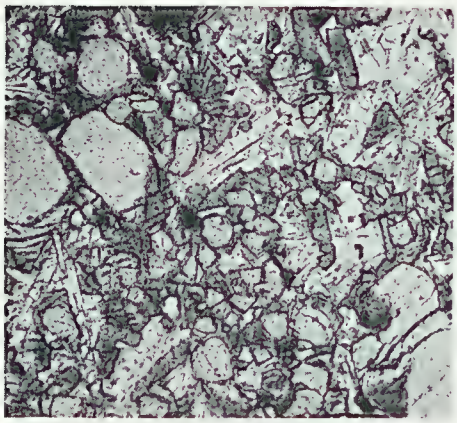

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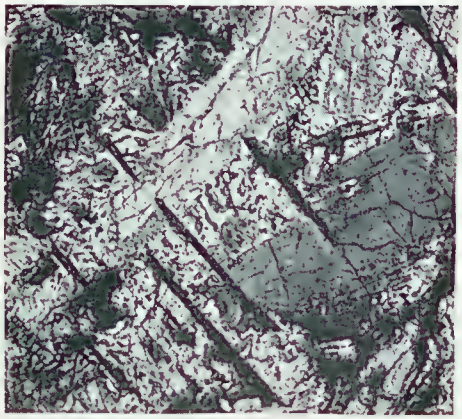

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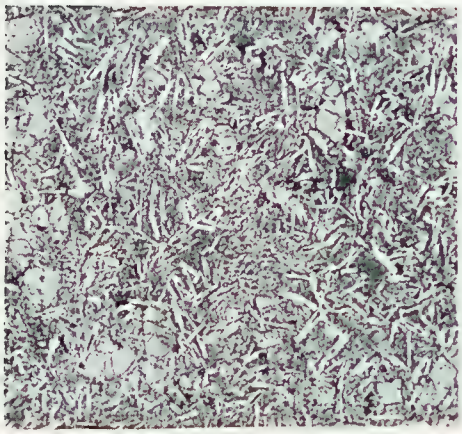

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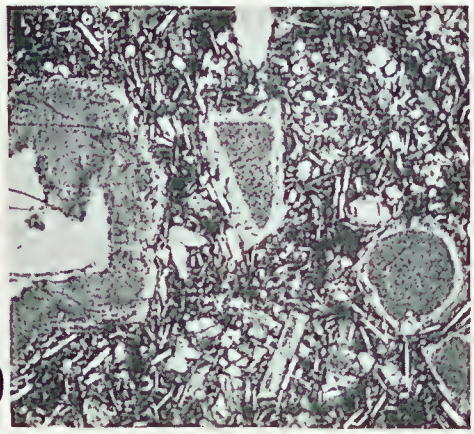

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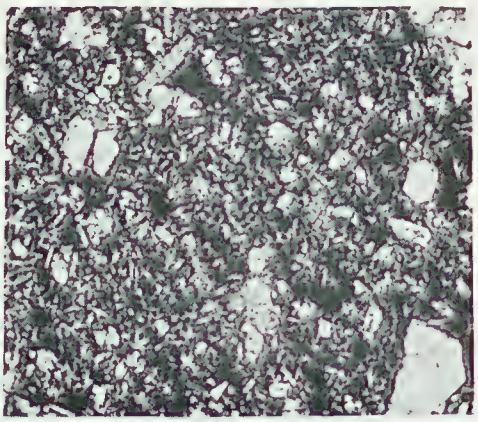

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DESCRIPTION OF *Brachaluteres wolfei, sp. nov.* (ALUTERIDAE) AND FIRST TASMANIAN RECORD OF *Urolophus paucimaculatus* DIXON, 1969 (UROLOPHIDAE)

By

E. O. G. Scott

(With two text figures)

ABSTRACT

A pigmy leatherjacket, *Brachaluteres wolfei, sp. nov.* (Aluteridae) is described and figured from the holotype and a paratype, dredged off the east coast of Tasmania in Schouten Passage in 10 fathoms, and an account and a figure are given of the first recorded Tasmanian example of the stingaree *Urolophus paucimaculatus* Dixon, 1969 (Urolophidae), trawled in Bass Strait off the Hogan Group in 60-61 fathoms.

Family UROLOPHIDAE

Genus **UROLOPHUS** Müller & Henle, 1837

Urolophus paucimaculatus Dixon, 1939

(Fig. 1)

Urolophus paucimaculatus Dixon, 1969, *Vict. Nat.*, 86, 1: 11-18, pl. I-III. Type locality: Bass Strait, approximately 13 miles off Cape Patton, Victoria; 40 fathoms.

Urolophus—'an undescribed white-spotted long-tailed species', Harrison & Scott, 1969, *Tasm. Fish. Res.*, 3, 1: 7-11 (pp. 9, 10, 11 dated, in error, January 1960): Bass Strait, off the Hogan Group; 60-61 fathoms [present specimen].

First Tasmanian record.—The first record from Tasmanian waters of this recently recognised stingaree is afforded by a male example, total length 297 mm, disc width 191 mm, trawled in Bass Strait, off the Hogan Group, on 19 January 1968 by the Japanese research vessel *Umitaka Maru*, the specimen being part of the collection made on board by Mr A. J. Harrison, Marine Biologist, Fisheries Division, Department of Agriculture, who was seconded by the Tasmanian Government to the ship for the Tasmanian section of its cruise. Three trawls (UMOT 6803-6805) were made on this day (material pooled) between latitudes 39° 06.4′ S. and 39° 10.3′ S., and between longitudes 147° 14.2′ E. and 147° 21.0′ E., at depths of 60-61 fathoms.

Description.—Disc wholly smooth; decidedly broader than long, its maximum width 1.30 its greatest length (to hindmost point on pectoral), or 1.16 length to hindmost point on pelvics, or 0.643 of total length of fish; produced into small but well defined subtriangular rostrum, with base about thrice its length, base subequal to longitudinal diameter of eye; anterior margin rather gently sinuous, exhibiting, on each side, four slight convexities, the point of inflection of the first laterad of median axis of fish by a distance subequal to length of spiracle, that of the second about twice as far laterad, that of the third, which is on horizontal level of a point about midway between front of eye and anterior wall of cranium, laterad of axis by about four times length of spiracle, or by half length of tail (appendage), that of the fourth at angle of disc; hinder lateral margin well rounded, thinned out to a narrow translucent slip that tends to have one crenulation at the tip of each ray, this small lobe entire, or, especially in anterior half of this region, with 1-5 microscopic lappets; posterior corner rather pointed; inner margin virtually straight in earlier three-fourths, gently concave at attachment of fin, its length subequal to width of base of tail.

Tail wholly smooth (except for caudal spine); without dorsal fin; length, from centre of cloaca, 1.37 distance of centre of cloaca from front of mouth, subequal to (1.01 times) distance from snout-tip to middle of cloaca; the free appendage originating, on lower surface, behind vent by a trifle less than twice length of vent, 1.8 times as wide as deep at its base, width here half interval between 3rd gill-slits, dorsal surface moderately, ventral surface barely, convex. Caudal spine stout, straight; depressible for almost its entire length into a shallow groove; dorsal surface convex, ventral flat with median ridge; origin at 0.488 of tail from middle of cloaca; total length subequal to interval between 3rd gill-slits, almost twice its free length (facing tail); at present carries 30 (right), 33 (left) well developed backwardly directed recurved lateral teeth (since specimen was measured terminal 1.5 mm has been lost; this could carry one or two more teeth). Caudal well developed, lanceolate, somewhat bluntly rounded; height about one-third its superior length, or equal to length of spiracle; lower lobe with 44, upper with 38, rays; length to origin, located about below insertion of spine, at 0.565 of tail-length; lobe extending back as a mere ridge about to level of origin of upper lobe, which is at 0.707 of tail-length, barely in advance of tip of adpressed spine. Two well developed lateral dermal ridges, beginning about as far behind origin of free tail as latter is behind vent; extending to level of origin of inferior caudal lobe, their total extension subequal to distance of their termination from tip of caudal fin.

Lengths to orbit, to anterior margin of soft eye 0.42, 0.44 in width of disc; longitudinal diameter, transverse diameter of orbit 3.3, 4.3 in length to orbit; longitudinal diameter of eye 4.1 in length to eye, or 1.4 in hard interorbital, or 2.1 in distance between free margins of eyelids. Spiracle originating just in advance of first one-third of orbit, extending behind orbit by about two-fifths of longitudinal extension of latter; curving round half

or more of posterior border of orbit, its total transverse extent about half its length; length of virtually linear, forwardly and inwardly sloping inner margin behind orbit about half longitudinal diameter of eye; minimum, maximum interspiracular distance 1.4, 1.8 length of spiracle; opening can be completely closed by a membranous flap developed along inner margin.

Internasal valve (fig. 1*b*) with lateral borders markedly sinuous, the main convexity the anterior, occurring at about the anterior one-third, constituting a rather well defined lobe with external surface somewhat elevated marginally, internal (hidden) surface convex; posterior border with a median notch, on either side of which it is mainly gently convex (barely concave laterally), bearing about 50 small lobes, simple or exhibiting up to 4 lobules; border produced at either end as a well pointed triangular flap, longer than broad, extending laterally beyond angle of mouth and overlapping nasoral groove, this flap extending dorsad along its outer border to constitute inner wall of nasoral groove. Outer border of nostril and the very short region between its posterior termination and level of mouth echoing outer border of internasal valve, so that, when both are pressed flat, nostril is completely closed; the pennon at posterolateral angle of valve overlapping both nasoral groove itself and its outer wall arising briefly behind, and continuous with, outer nostril rim, and thence running forward, as a high curved ridge, for more than half length of nostril, to whose internal wall it thus contributes the hinder part. A superficial, transversely set *V* in the hinder part of lateral border of internasal valve, at anterior origin of posterolateral pennon, is matched in the outer narial wall by a blunt, broadly subtriangular lobe, somewhat elevated distally to project as a low process; on left side process simple, on right exhibiting a major lobule, followed behind by a second about half as large. In advance of, and dorsad of, this lobe, a curtain arising from outer nostril wall, and extending across general narial aperture, inside it, capable of closing over that part of nostril reaching forward beyond nasoral groove. A groove external to nostril, and with it delimiting a region developing behind, at about level of middle of anterior border of the somewhat elevated subtriangular nasal lobe, as a slender stalk, and expanding anteriorly to become bluntly ovate, the anterior point of the obscure platform thus constituted extending a little cephalad of narial aperture. Length to front of internasal valve more than twice minimum (anterior) width of valve, subequal to direct distance from angle of mouth to 2nd gill-slit; length to back of valve 2.8 its anteroposterior extension.

Mouth slightly arched, its width a little less than greatest width of internasal valve; length to anterior margin 4.71 in disc width, 2.1 mouth width, the latter half width between 2nd gill-slits. About a dozen small blunt closely set papillae along external surface of median three-fifths of lower jaw, of which only the inner half dozen are well differentiated by separation throughout much of their length; between these papillae and the teeth a line of less massive papillae, of which 4 central ones bear a terminal shining, translucent, subconical projection. Teeth closely set, in about 24 diagonal rows in upper jaw, in about 28 diagonal rows in lower jaw; quadrangular, each with an erect, rather blunt subconical cusp, a little higher than broad. Immediately behind teeth in upper jaw a low velum with virtually even free border; behind this a longer frenum, all, or almost all, whose free margin is formed by about 20 long subtriangular lappets. Behind teeth in lower jaw a very low, rudimentary curtain, significantly developed in less than middle half of jaw; behind this 5 erect mesial buccal papillae, 3 clustered together, subcontinuous, their blunt tips with a few very low tubules, 1 at each side, large, with 2 well developed bluntly lanceolate terminal lobes extending laterally, the angle between their main axes about 150° (fig. 1*c*).

Gill-openings small to moderate; 1st behind snout-tip by 0.33, 5th by 0.44, of disc width; distances between inner margins of 1st, of 5th, pair 0.65, 0.32 of their respective lengths from snout-tip, the first interval subequal to direct distance from 1st gill-slit to angle of mouth on opposite side. Claspers about two and one-third times as long as broad; length (a little greater on right than on left) about equal to direct distance from inner base to front of cloaca; distance between bases subequal to distance between one base and hind border of cloaca.

Irregularly scattered minute pores, typically with low, minutely lobulated rim, behind mouth, and covering more than two-thirds of area between the gill-slits back to about level of 4th slit, modal distance between pores in anterior, more crowded part of this area about 1½ mm, in less crowded posterior part about 2 mm; extending laterally between mouth and 1st slit almost to margin of disc, average distance between pores near middle of this region about 5 mm. Fewer than a dozen rimmed pores observed on lower surface of disc outside areas noted above; none on lower surface of tail. On upper surface of disc, on each side of median line, a longitudinal series of 8 pores, converging somewhat posteriorly, anterior pore of each series about as far from posterior pore of same series as from the other anterior pore, this distance two-thirds of distance of an anterior pore from its spiracle. Lateral line, ear openings not observed.

General colour of upper surface of disc (formalin specimen) rich darkish brown, almost uniform; very narrow edging, round entire margin, of opaque whitish (anterolateral and short posterior borders) or translucent whitish (posterolateral border). Upper surface with white markings as follows. (*i*) A linear series of 4 sharply delimited spots, about equally spaced, on each side of head and body along pectoral base; the two not identical, that on the left comprising (*a*) obliquely oval spot, major axis 5 mm, wholly bordered faintly with dark brown, just behind, and externad of, hind end of spiracle, in direct distance about an orbit-length from orbit; (*b*) behind, somewhat internad of, last, rounded subrectangular, annulated, somewhat incompletely, with very dark brown; (*c*) directly behind last, largest spot, rectangular, conspicuously surrounded with very dark brown; (*d*) behind, somewhat externad of, last, subcircular, vaguely ringed with darker: of the series on the right

TABLE 1

Urolophus paucimaculatus Dixon 1969. Dimensions, expressed in thousandths of total length (*Tlt*), 297 mm of a Tasmanian male, trawled in Bass Strait, off the Hogan Group, 19 January 1968

Feature	*Tlt*
Pectoral:	
Maximum width (disc)	643
Length to inner margin	495
Length to hind border	552
Pelvic:	
Length to anterior insertion	471
Length to fold at junction with clasper	552
Length to hind border	599
Width of base; between parallels, oblique	81, 104
Interval between bases	148
Clasper:	
Length to tip	623
Inner length	71
Outer length	44
Cloaca:	
Length to anterior, to posterior border	485, 508
Tail:	
Total length (from middle of cloaca)	503
Free length (dorsal aspect)	448
Width at free base	61
Depth at free base	34
Length to origin of lateral dermal fold	576
Length to termination of lateral dermal fold	781
Length to origin of spine	754
Total length, free length, of spine	119, 65
Length to origin of caudal fin; inferior, superior	781, 852
Maximum depth of fin	49
Gill-slits:	
Lengths to slits I-V	209, 232, 253, 269, 283
Intervals between members of pairs I-V	135, 128, 114, 98, 90
Orbit:	
Length to anterior border	145
Length	44
Interorbital (between tops of ridges)	51
Eye:	
Length to anterior border	152
Length	37
Interocular; internal border, external border of eyelids	61, 77
Spiracle:	
Length to anterior border	162
Length	49
Interspiracular distance; maximum, minimum	120, 90
Mouth:	
Length to anterior border	136
Width	64
Nasal opening:	
Length to anterior border	99
Length	24
Internasal valve:	
Width; maximum (posterior), minimum (anterior)	73, 47
Length	35

(*b*), (*c*), (*d*) agree in location, size, character of dark rims with (*a*), (*b*), (*c*) on left side, while the unmatched (*a*) is a rather smaller subcircular white spot without obvious dark border, at level of front of orbit, collinear with (*b*), (*c*), (*d*). (*ii*) Irregular whitish patches, not sharply defined, include a region immediately behind right eye, subequal in area on right to whole eye, but less extensive, and less clearly defined, behind left eye; some small areas inside, and in advance of, anterior one-third of each eye; an indistinct splash a little to the right of the median line, near the level of the last regular white spot of the right series. General colour of lower surface of disc whitish, with some indistinct purplish suffusion; a conspicuous brownish border, scarcely in evidence in front of level of nostrils; starting from virtual zero at this point, quickly reaching its maximum width (on left, subequal to length from snout-tip to level of nostril; on right, a trifle less), thence decreasing in width to about middle of posteroexternal border of fin (being here about two-thirds of maximum width, or about half length to mouth); behind this continuing without marked change in width to end of pectoral, where it becomes just continuous with dark colour of upper surface of pelvic. Ventral surface of pelvics white, with dark brown border, somewhat more slatey than that of pectoral, occupying roughly the area external to a straight line drawn from anterior origin of fin to junction with clasper. Claspers dark brown on their narrow dorsal exposure, clear white below, whitish on internal surface facing tail.

Dimensions.—Greatest width of disc 191 mm; disc length (to level of end of pectorals) 164 mm; length from tip of rostrum to middle of cloaca 147.5 mm; total length 197 mm. Other dimensions, expressed as thousandths of total length, are set out in table 1.

Note added in press.—In this contribution as presented to the Royal Society of Tasmania on 30 September 1968 the present specimen was described as the holotype of a new species, named after the collector. The fact that publication of a subsequently submitted paper, based on Victorian material of this form (Dixon, 1969), is expected prior to the appearance of this paper has rendered necessary the cancellation of the specimen's status as a type, with reduction of its treatment here to that of a report on the first Tasmanian example of the newly recognised form—this rehandling involving, in addition to the making of contingent formal modifications, the omission of a fairly extensive discussion of species affinities in *Urolophus*.

To obviate possible later nomenclature confusion, it is necessary to make, at date of proof reading (March 1969) an addition to the preceding paragraph (incorporated in original manuscript, as rehandled in January 1969). The present specimen is recorded as '*Urolophus*—an undescribed white-spotted long-tailed species' in a systematic list of fishes collected in Tasmanian waters by the *Umitaka Maru* in January 1968, by ed. J. Harrison & E. O. G. Scott, published in January 1969 in *Tasmanian Fisheries Research*, Vol. 3, No. 1 (publication delayed; originally envisaged for September 1968, subsequently for December 1968): the statement at the end of the list (p. 11) that 'a description' of the ray as a new species 'has been submitted elsewhere for publication' refers to the present paper in its original form. It unfortunately proved impracticable to make in the paper on the *Umitaka Maru* material an emendation recognizing the appearance of the description of Victorian material as *Urolophus paucimaculatus* Dixon, 1969 in the same month. In *Tasmanian Fisheries Research*, 3, 1 the date of publication appears incorrectly on pp. 9, 10, 11 as January 1960; being correctly given elsewhere as January 1969.

Family ALUTERIDAE

Genus **BRACHALUTERES** Bleeker, 1866

Brachaluteres wolfei, sp. nov.

(Fig. 2)

Description.—Compressed, high, short, ovoid; greatest depth 1.20, 1.38 (holotype, paratype; cited similarly throughout) in standard length (*Ls*), at about level of dorsal spine; depth at origin of soft dorsal 1.25, 1.49 in *Ls*. Abdomen distensible, hanging loosely in the form of a dewlap, into which the intestines descend; no thin membranous edge, at vent as thick as, or thicker than, back. Dorsal profile slightly convex for one-third snout; slightly concave to front of orbit; evenly convex to dorsal spine; first one-third of interorbital almost flat, second third very gently sigmoid, last third rising sharply, convexly to origin of soft dorsal; below the dorsal highly arched, descending abruptly at end of end of base, which thus comes to constitute a convex elevated strip; changing direction markedly at beginning of peduncle, and proceeding caudad with a very slight, or moderate (paratype), concavity, then rising slightly and briefly just before caudal base. Ventral profile to level of lowest point an overall convexity, resolvable into two and a half minor sigmoid curves; convex to origin of anal; thence, with sudden change of direction, convex to anal termination, with fin base extending below general body profile, whose general course it follows, as a compressed ridge; on caudal peduncle, with abrupt change of direction, ascending gently, or more steeply (paratype), in both specimens a little sigmoid. Head from most anterior point, chin (full head) 1.25, 1.49, head from tip of upper jaw (strict head) 1.33, 1.54, in *Ls*. Eye 6.8, 4.6 in full head; 2.04, 1.58 in snout including lower jaw, 1.51, 1.12 in snout from tip of upper jaw. Orbital rim somewhat elevated.

Dorsal spine (fig. 2*c*) originating just behind eye; depressed, extending about 0.6, 0.5 of distance towards second dorsal; direct distance (dividers) from tip of snout to front of spine base 1.61, 1.60 distance from last-mentioned point to first dorsal ray, or 1.26, 1.10 full head; distance from dorsal spine to nearest point on orbit 1.45, 1.14 eye, or 1.78, 1.43 distance from middle of orbit to dorsal profile vertically above it; much longer in holotype, length 1.94, 3.07 in full head; stout; markedly, barely (paratype) sigmoid; anterior surface convex, posterior concave; sharply acuminate distally, the tip in holotype (possibly also originally in paratype) protected by rounded fleshy mass; anterior surface beset, very closely in holotype, with conical flesh-covered projections not in regular rows, about 6-9, about 4-5, side by side extending right to, stopping short of, base of spine, in holotype becoming more slender, more acute near tip; posterior surface smooth. Dorsal membrane attached to spine almost to tip and along back for a distance subequal to length of spine. Spine depressible into a groove; no sign of a locking spine. Interdorsal 5.40, 3.52 in head.

Soft dorsal with 27, 27 rays; rising rapidly to 11th and 12th rays, then decreasing steadily, more sharply in last few rays; lengths of 1st, 5th, 10th 11th (and 12th), 15th, 20th, 27th rays of holotype 3.1, 1.5, 1.3, 1.27, 1.4, 1.5, 2.5, 2.6 in strict snout; length to origin 1.71, 1.60 in *Ls*, subequal to height at anal origin; base, between parallels, 3.21, 3.60, or, directly with dividers, 2.59, 2.68, in *Ls*, the measurement with dividers subequal to caudal fin plus caudal peduncle, to caudal fin (paratype).

Anal with 25, 25 rays; originating behind dorsal; general form as in dorsal, with greatest height at 11th and 12th rays; lengths of 1st, 5th, 10th, 11th (and 12th), 15th, 20th, 25th rays 2.1, 1.5, 1.5, 1.4, 1.5, 1.8, 1.9 in strict snout; length to origin 1.38, 1.51 in *Ls*; terminating slightly behind dorsal; base between parallels, 4.88, 4.02, or, directly with dividers, 4.00, 3.21, in *Ls*, the measurement with dividers subequal to combined eye and strict snout.

Pectoral with 10 (left), 10 (right), 10 (left), 11 (right) rays; moderate; its length 0.9, 0.9 strict snout, slightly exceeding minimum depth of caudal peduncle; its longest (4th, 4th) ray 1.2, 1.1 eye; originating just in advance of, just behind, posterior orbital border. Caudal 12, 12, rays in two closely opposed fans of 6 each; rounded; base 0.9, 0.9 depth of end of caudal peduncle; length 1.05, 0.95 head.

Gill-opening above pectoral base; its posterior border, its whole extent (paratype) immediately behind level of eye; visible opening an oblique oval with length a trifle less than half an eye-diameter, but the addition of a superior slit, covered by a membranous flap, makes total length 0.7, 0.8 an eye-diameter; direct distance from orbit just less than full length of opening, from origin of soft dorsal 2.41, 2.81 in *Ls*, from origin of anal 2.12, 2.30 in *Ls*. No pelvic spine; pelvic bone small, reaching three-fifths of the distance from its lower end to lower lip. Lateral line not evident. Depth of caudal peduncle, just before caudal base, 2.1, 1.6 its own length, slightly exceeding interorbital.

The whole general surface of the fish is almost velvety, very slightly prickly: the feel is about the same whether the finger is drawn forward or backward. Scales (fig. 2*b*) small, oval, closely set: each with about a score, or fewer, well developed ridges radiating from a point near, often somewhat behind, its centre; arising from point of radiation of ridges an erect flexible bristle, straight or very slightly curved, slender, of constant diameter through nine-tenths, or more, of its length, expanding moderately and briefly at its attachment and rounding off distally to a blunt, or somewhat pungent, tip; bristles continuously, and fairly evenly, disposed over head, trunk, tail (smaller, more crowded on both surfaces of pectoral base), intervals between them anteriorly subequal to, posteriorly rather less than, their height; longest on trunk (where in holotype they reach a length of 0.6 mm), a little shorter elsewhere; bristles on head, in what is perhaps the normal, undamaged condition, sheathed in clear membrane, which on one face (commonly the posterior) bulges, in distal one-third or so, as an ovoid swelling in which are enclosed 1, 2, 3, or a small group of rounded melanophores; elsewhere many bristles on which fleshy bulge has collapsed (or is missing?) still exhibit 1 or 2 conspicuous black dots. In holotype, and less clearly in paratype, scales disposed in about a score of forwardly concave rows between level of dorsal spine and caudal base, the anterior 4-5 not traceable below

level of lower border of orbit, the remainder extending continuously between dorsal and ventral profiles; approximately 80 scales between soft dorsal base and vent.

Dental formula $\frac{3+3}{2+2}$. In upper jaw (fig. 2*d*) the four inner teeth, viewed frontally, present the outer surfaces, convex both vertically and transversely, of four blunt hyaline half-cones (internal oral surface flattish or concave); each half-cone surmounted by a subtriangular horn-coloured plate, the plates of the two inner teeth having vertical internal borders, these being closely opposed to each other, so that the two inner half-cones come to be surmounted by a single composite subtriangular plate, giving a net set of three horn-coloured cusps; these three cusps soldered to the four hyaline half-cone summits by hyaline material, almost flat externally; half-cones themselves soldered together, by flattish hyaline sheets, from their bases upwards, the matrix expanding distally to fill all the space between the horn-coloured cusps, its free outer border somewhat thickened, the cutting edge between each outer tooth and its neighbour thus coming to constitute a deep concavity, the middle of which is hyaline, the sides horn-coloured. Lying at the angle of the gape laterad of, and well separate from, each external tooth of the set of four noted above is a low long tooth, subrectangular, with its distal angles rounded; its cutting edge subvertical, virtually rectilinear throughout most of its length; its base subequal to combined bases of the two teeth nearest it; its height about half height of adjacent tooth; set in hyaline matrix continuous above with adjacent tooth, and extending below well beyond this most lateral tooth itself. Teeth in lower jaw (fig. 2*e*) presenting three net cusps, as in upper jaw, but teeth here wholly hyaline, lacking terminal horn-coloured plate; central cusp highest; each tooth with its sides strongly sinuous (except closely applied inner borders of the two inner teeth), narrower basally; inner tooth overlapping outer, the latter also largely overlapped at its external border by third tooth of upper jaw.

The following account of coloration is based on the holotype; no noteworthy variations are exhibited by the paratype, though in it the ground colours are rather less clearly differentiated, or paler, and some of the more obscure markings of the holotype are either even less clearly traceable or unrecognisable. No well defined discrete markings in the form of spots, bars, or stripes, other than a darkish circumoral band that continues as a tolerably well marked saddle over the snout; the more obscure markings (as preserved in alcohol; probably with some fading), in the form of indefinite darker regions, not always identical on the two sides (the more extensive here recorded). Three main ground colours can be recognised: (*i*) green, with, in places, a somewhat bluish tinge; (*ii*) greyish, the net outcome of a peppering of brownish chromatophores on the whitish integument; with a faint tinge of green, due to the presence of the mainly pale green bristles; (*iii*) isabelline, resulting from the combination of a whitish or somewhat yellowish flesh-coloured ground and a crowded assemblage of brown, or reddish brown, dots of variable concentration. The main areas occupied by these colours are: (*i*) whole of narrow dorsal surface (except for dark saddle across posterior half of snout); with extensions on to sides at tip of snout down to level of gape, at interorbital down to orbit, at from orbit to middle of interdorsal down to level of middle of orbit, and behind this as a narrow band below second half of interdorsal and along whole elevated base of soft dorsal; fringing posterior border, also, narrowly and imperfectly, superior and inferior borders, of caudal peduncle (these green areas on caudal peduncle somewhat more obvious in paratype); in an ill-defined arc covering the pubic bone and continuing down nearly to vent; in a band along elevated base of anal; (*ii*) most of the distensible belly; delimited above by lower border of skull; roughly delimited behind by an oblique line from pectoral base to vent; extending within these limits, except for the greenish arc along pubic bone, to ventral profile; (*iii*) the overall isabelline remainder of head, trunk, tail exhibiting variable intensity of punctulation with some local concentrations constituting usually more or less obscure darker areas, of which the most noticeable are the darkish circumoral band continuing upward to become the rostral saddle already mentioned; patches below interdorsal and early part of soft dorsal base, below hinder part of soft dorsal, on caudal peduncle, above and behind gill-opening. Dorsal spine dark green, whitish distally; membrane translucent, punctulated with reddish brown, more densely at base, and very densely in a fine line along external border. Soft dorsal and anal whitish. Pectoral base dark green proximally, with a more or less pellucid distal fold, whitish or very pale greenish, along bases of rays; rays faintly greenish, some somewhat yellowish distally; membrane colourless. Caudal with basal half pale orange, each ray with a row (on parts of some rays two or three rows) of closely set dots or short cross strokes; distal half greenish, rays immaculate, save that most of the internal ones are punctulated with brown for about half an eye-diameter at the tip. Visible walls of gill-opening white. Iris indeterminate fawnish, with some dark peppering superiorly, and with indication of two dark rings; pupil blackish. Lips white. Teeth almost colourless, hyaline, except (see above) for the three terminal horn-coloured subtriangular plates.

No conspicuous markings were observed in the fresh specimens; the above account probably represents a reasonable approximation to the disposition of the main colour-masses in life.

Fin counts and dimensions.—Fin counts of the two specimens, and their principal dimensions, expressed in thousands of standard length, are set out in table 2. For all dimensions measured from the anterior end of the body two values are entered in the table, the first obtained by starting from the most advanced point (tip of chin), the second by starting from the anterior border of the upper lip. The millesimals are based on standard length as measured from tip of chin.

Material.—Described from the holotype, *Ls* 42.0 mm, *Lt* 55.2 mm, and one paratype, *Ls* 24.1 mm, *Lt* 32.8 mm, made available for examination by the Fisheries Division, Department of Agriculture (fig. 2).

TABLE 2

Brachyluteres wolfei, sp. nov. Meristic data, and dimensions, expressed as thousandths of standard length (*TLs*), of holotype and paratype dredged off eastern Tasmania in Schouten Passage in 10 fathoms

Where two entries occur for one dimension, the first is measured from most advanced point (chin), the second from anterior border of upper lip: standard length is taken from chin to hypural joint.

Feature	*Holotype*	*Paratype*
	Ls 42.0 mm	*Ls* 24.1 mm
Dorsal	I, 27	I, 27
Anal	25	25
Pectoral: left/right	10/10	10/11
Caudal	12	12
Total length	1314, 1254	1361, 1336
First dorsal:		
Length to origin	383, 324	402, 377
Length to termination	429, 369	436, 411
Length of spine	155	124
Second dorsal:		
Length to origin	576, 517	627, 602
Length to termination	888, 829	905, 880
Direct length of base (dividers)	393	373
Lengths of 1st, 5th, 10th, 11th (and 12th) rays	57, 121, 136, 140	
Lengths of 15th, 20th, 25th, 27th rays	124, 117, 76, 69	
Anal:		
Length to origin	729, 670	664, 639
Length to termination	933, 874	913, 888
Direct length of base (dividers)	310	311
Lengths of 1st, 5th, 10th, 11th (and 12th) rays	83, 117, 121, 124	
Lengths of 15th, 20th, 25th rays	117, 98, 93	
Pectoral:		
Length to origin	262, 202	365, 340
Length of fin	164	183
Length of longest (*n*th) ray	140 (4th)	162 (4th)
Oblique length of base	74	83
Vent:		
Length to anterior border	650, 590	568, 544
Length to posterior border	714, 655	651, 626
Head	300, 240	382, 357
Snout	238, 179	228, 203
Eye	117	145
Interorbital	119	126
Gill opening:		
Apparent length	48	66
Total length	71	87
Depth:		
Maximum	833	726
At origin of second dorsal	798	672
Caudal peduncle at caudal origin	143	137
Direct distance (dividers) between:		
Base of dorsal spine and nearest point on eye	169	166
Middle of orbit and nearest point on dorsal profile	95	116
Gill opening and origin of first dorsal	307	328
Gill opening and origin of second dorsal	408	402
Gill opening and origin of anal	471	438
Gill opening and base of pectoral	14	12
Gill opening and nearest point of eye	60	58
Median anterior border of upper lip and origin of first dorsal	360	402
Median anterior border of upper lip and origin of second dorsal	557	456
Median anterior border of upper lip and origin of anal	788	701

The species is named in honour of Mr D. C. Wolfe, who collected the types.

Locality.—Off eastern Tasmania; mid-western end of Schouten Passage in line between Weatherhead Point and Supply Rock; dredged in 10 fathoms.

General discussion.—Only two species of *Brachaluteres* Bleeker, 1866 are generally recognised—see, *e.g.*, McCulloch (1929: 41), Fraser-Brunner (1941: 86)—namely, (*i*) the genotype *Aluterius trossulus* Richardson, 1846, type locality Western Australia [type specimen lost (Günther, 1870: 235)] (*ii*) *Aluterius? baueri* Richardson, 1846, type locality Australia, based on a drawing by Ferdinand Bauer (not seen), now (*fide* McCulloch, 1929) in the British Museum—Richardson was uncertain of its generic position, remarking that the drawing exhibited 'the undivided dental plate of *Diodon*, the inflated body and dermal spines of *Tetraodon*, and the fins of *Aluterius?*': the species was assigned to *Brachaluteres* by Waite (1903: 40). However, two additional descriptions call for notice: (*iii*) *Monocanthus oculatus* Günther, 1870, type locality Port Lincoln, South Australia; (*iv*) the form from Lord Howe Island described and figured by Waite (1903: 38, pl. iii, fig. 2), and identified by him as *B. baueri*. Of (*iii*) Waite stated 'I can confidently pronounce *M. oculatus* to be a synonym of *A. trossulus* Richardson, having a large collection showing perfect intermediate grades. It is in fact the ocellated colour-pattern of *M. oculatus*, which is described and figured by Hollard[37]' [Footnote: '[37] Hollard—*Ann. Sci. Nat. Zool.* (4), iv, 1855, p. 6, pl. 1, fig. 1']. This identification is formally accepted in the Check-List (distribution given as Australia, Lord Howe Island): Günther's species is rejected also by Fraser-Brunner [without recorded synonymy, leaving unstated whether he sinks it in (*i*) or in (*ii*)]. The insertion of the dorsal spine is in (*i*) 'over the middle of the eye', (*ii*) no data in Richardson or in Günther, (*iii*) 'behind the eye', (*iv*) 'above the middle of the eye'. In synonymising (*iii*) with (*i*) and presenting a diagnosis of (*ii*) in terms of (*iv*) Waite, it will be seen, fails to extend recognition to any form with a first dorsal originating behind the eye. Failing an assumption that the insertion of the dorsal spine varies within a species from above the middle of the eye to behind the eye—a possibility that, in view of the marked stability of the location of the spine in other aluterids, seems decidedly remote—the identification of Günther's species with *B. trossulus* appears unwarranted. Waite's identification of his Lord Howe Island material as *B. baueri* would extend the soft dorsal count for that species, as given by Richardson, from 26-27 to 29, and, more notably, the anal count from 21 to 26; for differences in pectoral and caudal counts, see below: agreement in colour-pattern is very satisfactory. The validity of this concept of *B. baueri* receives strong, if indirect, support from the fact that Fraser-Brunner admits in *Brachaluteres* only that species and *B. trossulus*.

The original pectoral and caudal counts for *B. baueri* (6-7, 9) are lower than those for *B. trossulus* (11, 12) and than those for Waite's fish (10-11, 12); no data for *B. oculatus*. These low values are probably accountable for by their derivation from a drawing. An unduly low caudal count could well arise from the fact that in the Aluteridae the caudal rays are characteristically inserted alternately in two vertical planes, so that while one ray is more conspicuous when the fish is viewed from, say, the left side, the two rays immediately flanking it are more conspicuous when the fish is viewed from the right side. The low number of pectoral rays reported is probably explicable by difficulty, either in depiction or in counting, consequent upon the small size of the fin.

From all the published forms (*i*)-(*iv*), as interpreted by Waite and as recognised in the Check-List, *B. wolfei* is trenchantly distinguished by the insertion of the dorsal spine behind the eye. From *B. oculatus*, taken, as in the original description, as having the spine behind the eye, it is separable (*a*) by higher dorsal and anal counts (27, 25; *cf.* 24, 22); (*b*) by the absence of anything more definite in the way of colour-pattern than a dark circumoral band extending as a saddle over snout and several obscure dark patches elsewhere (*cf.* 'with about nine rather irregular longitudinal rows of purplish ocelli edged with white, and about as large as the pupil of the eye'). In its lack of black specks, and of white or blue spots tending to form lines on the lower parts it differs from *B. trossulus*; and in its lack of seven interrupted dark brown longitudinal stripes and nine short bars radiating from the orbit from *B. baueri*.

Note on dentition.—The present specimens cast some additional light on the curious matter of the dentition in this genus. The available data may conveniently be considered chronologically. (*a*) In his description of *B. trossulus* Richardson. (1846: 68) makes no mention of the teeth, but in his account, on the same page, speaking of *B. baueri* he observes of Bauer's figure 'it exhibits the undivided dental plate of *Diodon*'. (*b*) Of *B. baueri* Günther (1870: 235) states 'The artist has represented a dentition similar to that of *Diodon*, but with notches on the edges of the jaws', and he immediately goes on to add 'Also the single teeth are not so well differentiated in *M. oculatus* as in other Monocanths; but it then remains uncertain whether this is not due to the young age of the individual. I could distinguish four teeth clearly in the upper jaw, but two only in the lower'. (*c*) Waite, having first remarked (1903: 40) that Günther 'appears to have had very grave doubts as to the correct representation of *A. baueri*, for, though, unlike Emery, Bauer was a skilled draughtsman, he was not an Ichthyologist, and would fail to appreciate the necessary characters', he then sets out, in a separate paragraph of his description, the statement 'The teeth do not differ from those of typical monocanths'.

A comparison of the teeth of *Brachaluteres wolfei* with those of half a dozen other Tasmanian Aluteridae shows: (*a*) apart from individual variations (one large example of *Scobinichthys granulatus* (Shaw), 1790 has two small supernumerary teeth in right side of upper jaw) they all agree in dental formula $\left(\frac{3+3}{2+2}\right)$, and in the general disposition of the teeth, including the presence in the angle of the mouth of a subrectangular tooth with a more or less vertical cutting surface; (*b*)

in some small specimens of other species, with standard length of the order of 50 mm, the cutting edges of the middle two pairs of teeth, instead of being pointed in the upper jaw and pointed and excavate in the lower jaw, are nearly linear in both jaws, all these teeth usually being hyaline throughout, but those of the upper jaw exhibiting in one form a narrow subrectangular amber strip at the free margin; (*c*) the close apposition of the front teeth may lead to the formation of a more or less continuous dental wall, most noticeable in some smaller individuals; (*d*) the situation found in the present examples of *B. wolfei,* with the subconical front teeth of the upper jaw embedded in a hyaline matrix and surmounted by subtriangular horn-coloured plates, was not paralleled in the material examined. It may thus be concluded that at least some species of *Brachaluteres* exhibit, in the upper jaw, an arrangement of the more readily visible teeth that involves an unusual measure of fusion—of which Richardson and Günther found some indication in Bauer's drawing of *B. baueri,* but which Waite reported does not occur in material examined by him and referred to that species.

References

Dixon, J. M., 1969—A New Species of Ray of the Genus *Urolophus* (Elasmobranchii: Urolophidae) from Victoria. *Vict. Nat.* 86, No. 1, pp 11-18, pl. I-III.

Fraser-Brunner, A., 1941—Notes on the Pelectognath Fishes—VI. A synopsis of the Genera of the Family Aluteridae, and descriptions of Seven new Species. *Ann. Mag Nat. Hist.* 8 (11), 45: 176-199, 9 text figs.

Gunther, A., 1870—*Catalogue of Fishes in the Collection of the British Museum,* Vol. VIII. London.

Harrison, A. J. & E. O. G. Scott, 1929.—A systematic list of the Fishes collected in Tasmanian waters by the *Umitaka Maru* in January 1968. *Tasm. Fish. Res.,* 3, 1: 7-11.

McCulloch, A. R., 1921—Notes on, and Descriptions of Australian Fishes. No. 2. *Proc. Linn. Soc. N.S.W.,* XLVI, 3: 457-472, pl XXXVII-XLI, 3 text figs.

————————, 1929—A Check-List of the Fishes Recorded from Australia. *Mem. Aust. Mus.* V, I-III (IV, Index, 1930).

Richardson, J., 1846—*The Zoology of the Voyage of H.M.S. Erebus and Terror . . .* 1839 *to* 1843, IV. London.

Waite, E. R., 1903—Additions to the Fish-fauna of Lord Howe Island, No. 3. *Rec. Aust. Mus.,* V, 1: 20-45, pl. I-III. 2 text figs.

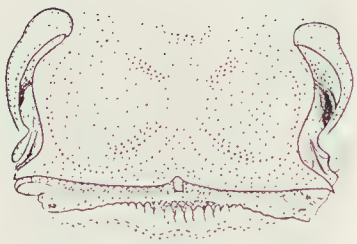

FIG. 1.—*Urolophus paucimaculatus* Dixon, 1939. First specimen recorded from Tasmanian waters; male; total length 297.0 mm, disc width 191 mm; trawled (*Umitaka Maru*) in Bass Strait east of the Hogan Group. *a.*—Dorsal aspect; × ½. *b.*—Nasoral region (note minor bilateral asymmetry; both postural and morphological; ×2. *c.*—Buccal papillae; × 3.

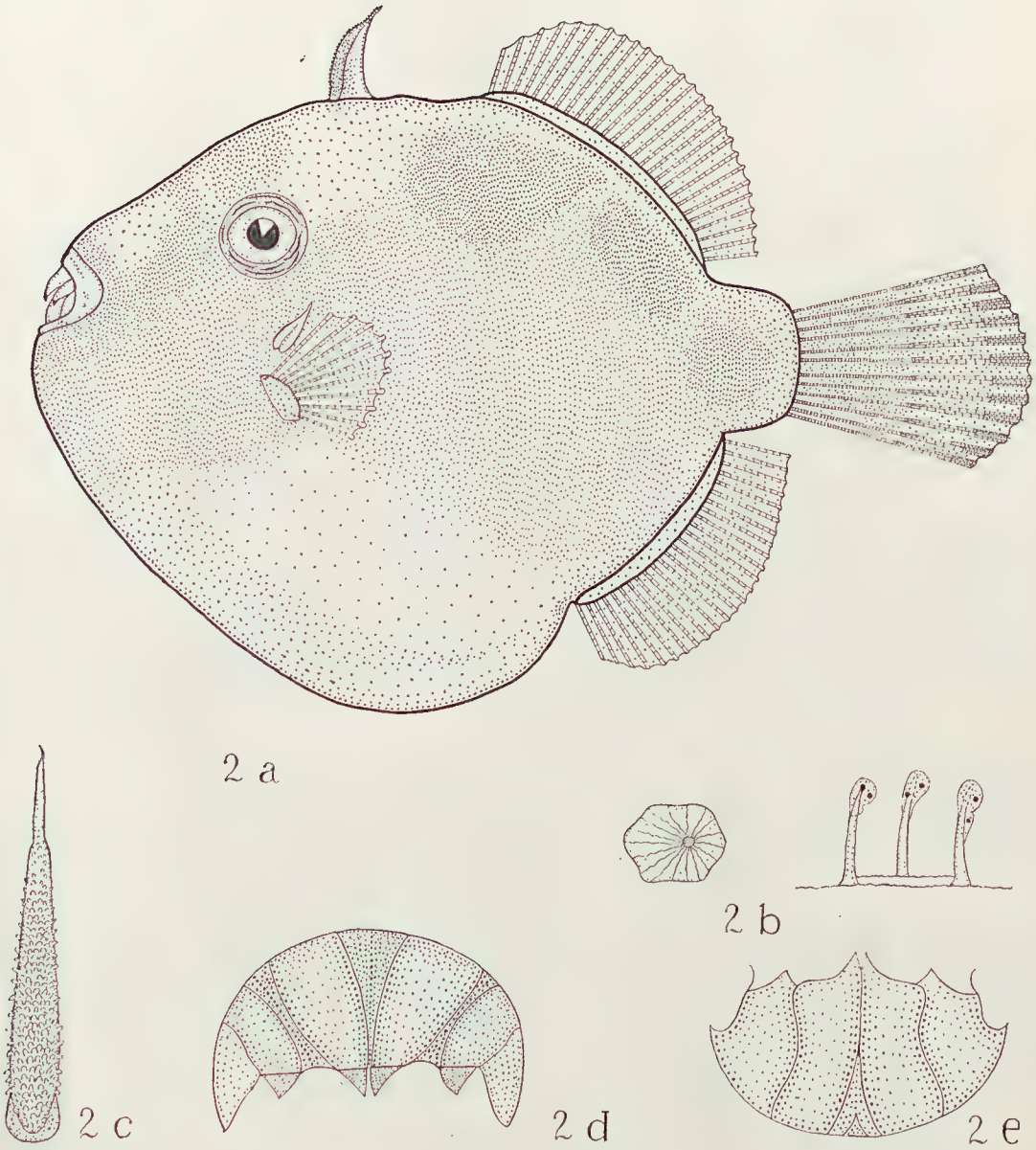

FIG. 2.—*Brachaluteres wolfei, sp. nov.* Holotype, total length 55.2 mm, standard length 32.8 mm; Schouten Passage (between Maria Island and mainland of Tasmania). *a.*—Lateral aspect; × 2½. *b.*—A scale external aspect (base only of bristle shown), and three bristles; all × 25. *c.*—Dorsal spine, anterior aspect; × 8. *d.*—Teeth of upper jaw (mouth tilted slightly downwards); × 15. *e.*—Teeth of lower jaw (mouth tilted slightly upward); × 15.

POLYPHASE FOLDING IN PRECAMBRIAN, LOW-GRADE METAMORPHIC ROCKS, MIDDLE GORDON RIVER, SOUTHWESTERN TASMANIA

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(With one plate and three figures)

ABSTRACT

New exposures on the southern side of the proposed damsite on the middle stretches of the Gordon River reveal unequivocal examples of polyphase folding in the Precambrian, low-grade metamorphic rocks of southwestern Tasmania. Three groups of folds are deformed by kink bands. The first group comprises very tight, almost isoclinal, and recumbent folds with north-south trending hinges, and was formed by considerable subhorizontal overriding of the western block towards the east. These early, concentric folds are folded by more open, similar folds. The hinges of the second group of folds pitch shallowly north-northeastward on steeply dipping axial surfaces parallel to which there is a prominent transposition foliation developed in the phyllites. These folds were produced by a steeply inclined thrusting of the eastern block towards the west during low greenschist-facies conditions of metamorphism. Small-scale, similar-style puckers pitching steeply in the transposition foliation comprise the third group of folds, and were produced by subsequent subhorizontal movement in the phyllites of the eastern block southwards.

INTRODUCTION

The middle reaches of the Gordon River are deeply entrenched in regionally metamorphosed, Precambrian quartzites, phyllites and schists. A possible damsite on the Gordon River (fig. 1), immediately upstream from the confluence of the Gordon and Serpentine Rivers, is currently being investigated by the Hydro-Electric Commission of Tasmania. In the new road cuts and other excavations excellent exposures of complex folds can be separated into three main groups. Polyphase fold deformation of the Precambrian rocks in southwestern Tasmania has long been suspected by Spry (1957, 1962(a) and (b), 1963), Gee (1963) and several other workers, but until now no unequivocal examples of refolding have been described.

The rocks vary from massive quartzites through quartzose phyllites to chlorite schists, and there are some graphitic bands. The quartz layers vary in thickness from mms to tens of metres, and layers of phyllite appear to be even thicker. Phyllite comprises a little more of the total rock than quartzite.

The distribution and intensity of the folding appears to have been controlled by the quartzite, and none of the deformations is truly penetrative. Each successive deformation has tended to pick out the zones which were least affected by earlier deformations. The first group of folds, G_1, occurs in bands where locally the proportion of pelite to psammite is greatest. The second group of folds, G_2, is the most widespread and penetrative on the larger scales, but does not affect the thicker quartzite lenses on smaller scales (pl. 1, No. 2). The third group of folds, G_3, does not affect the thick quartzite bands, and is most intensely developed in the phyllite.

It must be emphasised that this paper is only a preliminary study, and that the data were collected from one hillside only, viz.: from half-a-mile along the ridge immediately south of the proposed damsite. The area is well suited for detailed structural analysis and it is to be hoped that this work is extended before the dam fills.

Group 1 Folds

The earliest recognizable group of folds, G_1, is composed of tight to isoclinal folds with north-south trending hinges and variably oriented, though commonly shallowly eastward or westward dipping axial surfaces (fig. 2*a*). The G_1 folds range in size from centimetres (pl. 1, No. 1) to tens of metres, and some may even be larger.

The folds in the quartzite layers have concentric, or modified concentric profiles, with geometries corresponding to folds *flattened less than 30% perpendicular to the axial surface. Some of the folds (fig. 3*b*) have bulbous, globular profiles and curviplanar axial surfaces. The sense of coupling of the longer limbs of the folds is congruous with the G_1 deformation having been caused by an apparently subhorizontal movement of the overlying rocks towards the east. There is no well-developed cleavage associated with G_1 folds, although it is possible that it was obliterated during later deformation.

* *Flattening* (Ramsay, 1962, p. 312) was defined as a process of pure shear, and was measured (*ibid.*, p. 314) in terms of the variation of thickness in fold profile. An apparently flattened fold profile may, however, be the result of processes other than pure shear (e.g., simple shear), and thickness variations in one layer alone will not discriminate the mode of strain.

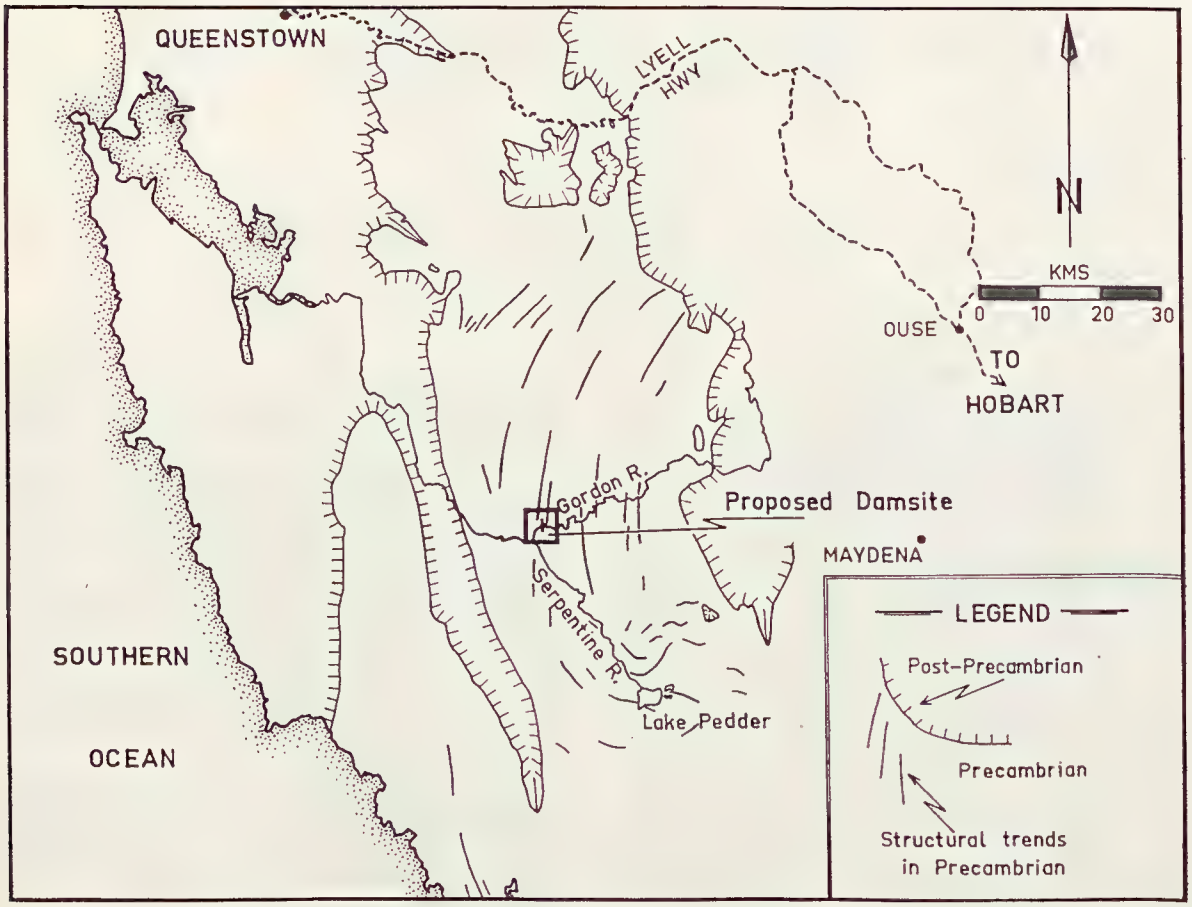


FIG. 1.—Structural location map of proposed damsite on Gordon River. (Modified from *J. geol. Soc. Aust.*, 9, Pt. 2, 1962.)

The variable orientations of the G_1 axial surfaces is attributed to rotation during the second phase of folding. Rotation of the folds about the G_2 axis to an arbitrary horizontal axial-plane position produces a strong north-south orientation of the G_1 hinges. Most of the G_1 folds were measured in two cuts along the road to the proposed powerhouse, and most of the G_2 folds from other outcrops to the south along the access road. Thus, in figure 2*b* the local axis of rotation of the G_1 folds has been used as the axis of unravelling rather than the statistical G_2 axis. However, although there is almost 20° divergence between this local axis and the statistical G_2 axis, almost the same distribution of G_1 hinges is obtained whichever axis is used in rotating the G_1 axial planes. The primary basis for distinguishing between G_1 and G_2 is whether refolding can be observed in outcrop, and peculiarities of style and orientation are subordinate criteria.

Group 2 Folds

The second group of folds has hinges which pitch shallowly north-northeastward on planar, steeply eastward-dipping axial surfaces. The profiles vary from open to tight, but are not isoclinal. G_2 folds are the most common and readily recognizable folds in the quartzite layers, and range in size from small puckers centimetres in wavelength (fig. 3*a*) to folds hundreds of metres across. The main anticlinorial structure of the damsite (Corbett, 1965) is a G_2 fold. In places the quartzite layers have been rolled up into large quartzitic rods, ten of metres across (fig. 2*e*), which in profile are more or less disconnected from each other giving the appearance of sigmoidal 'tectonic fish'. A false impression of massive quartzite ridges parallel to the fold axis is produced where such rods cap topographic highs.

The G_2 folds in the quartzite layers have profiles of Class 1c (Ramsay, 1967, p. 366) which correspond to concentric folds flattened a little more than the G_1 profiles. The G_2 folds in the pelitic layers have profiles of Class 3 (*ibid*), so that the entire fold is propagated in the axial surface by alternations of profiles of Classes 1c and 3 producing a Class 2 (similar) fold.

The sense of coupling of the longer fold limbs together with the shallowly eastward-dipping

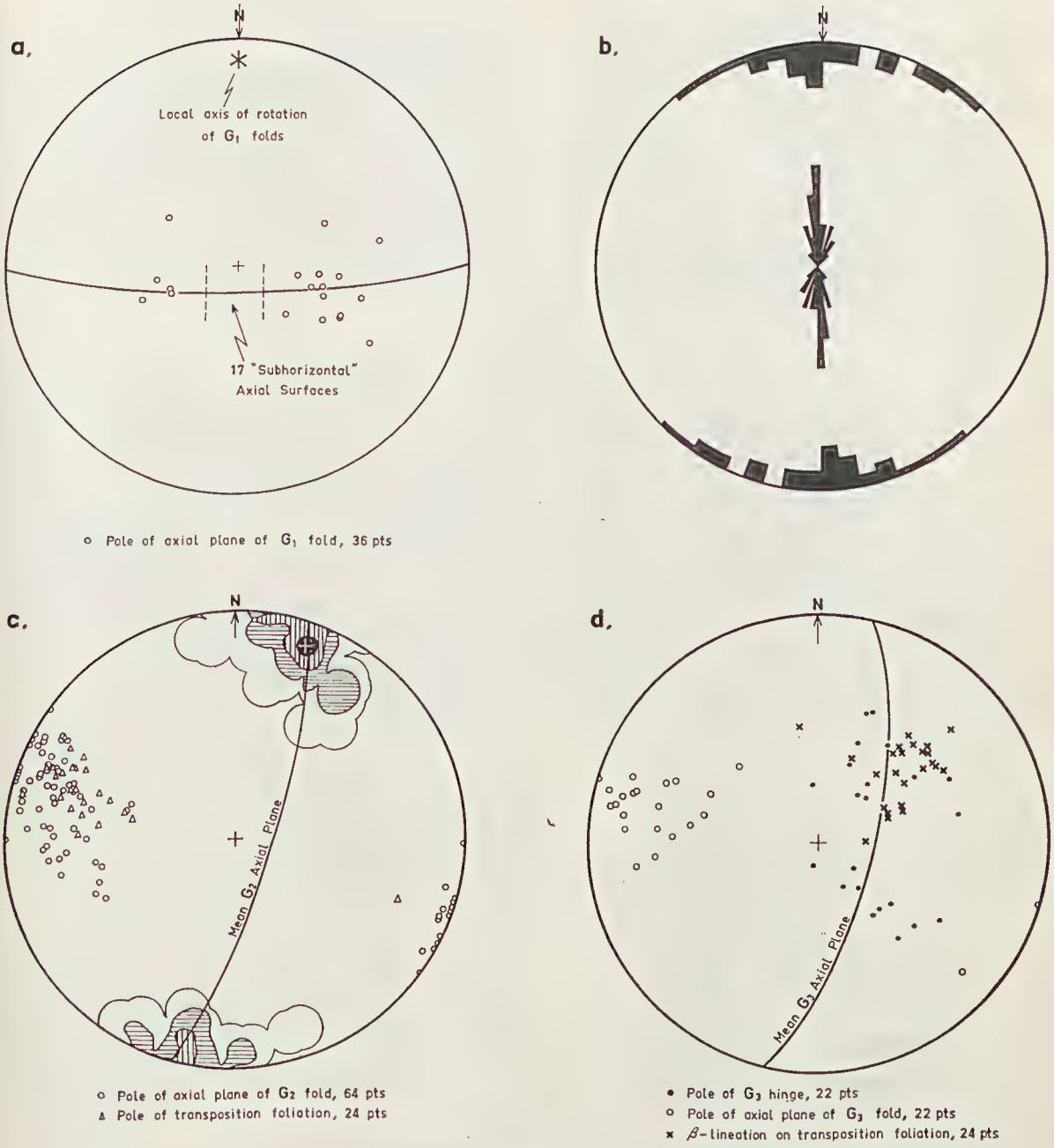
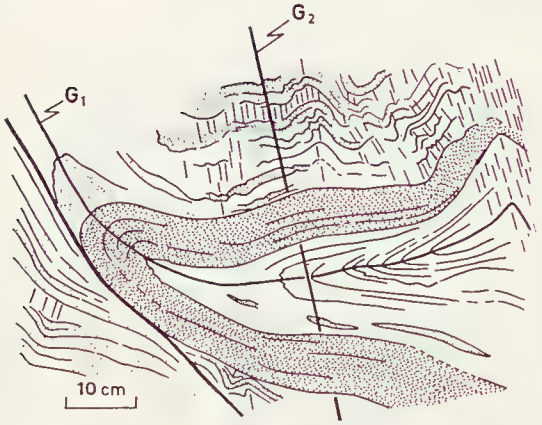
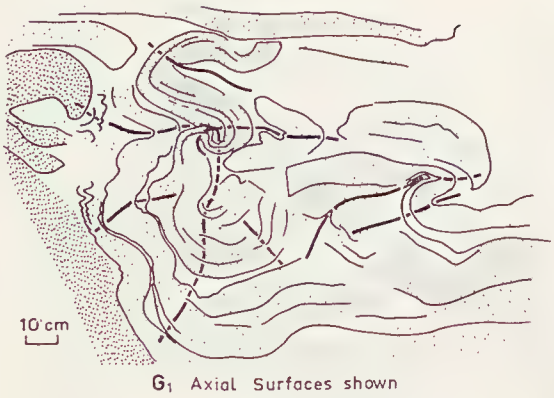

a.
N
Local axis of rotation of G_1 folds
17 "Subhorizontal" Axial Surfaces
o Pole of axial plane of G_1 fold, 36 pts
b.
N
c.
N
Mean G_2 Axial Plane
o Pole of axial plane of G_2 fold, 64 pts
Δ Pole of transposition foliation, 24 pts
d.
N
Mean G_3 Axial Plane
• Pole of G_3 hinge, 22 pts
o Pole of axial plane of G_3 fold, 22 pts
× β-lineation on transposition foliation, 24 pts

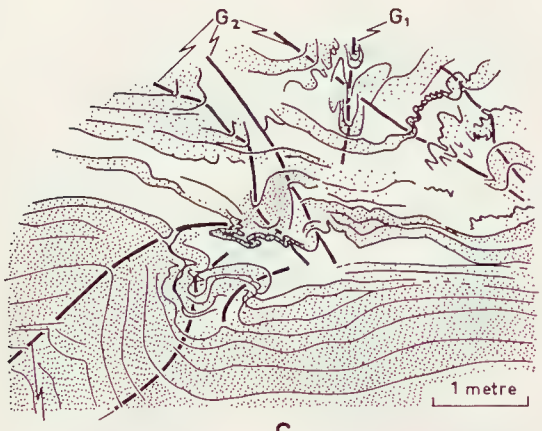
FIG. 2.—Structural elements of the three groups of folds. (*a*), (*c*) and (*d*) are Schmidt equal-area projections. (*a*) Poles of the G_1 axial planes. (*b*) Rose diagrams of 36 G_1 fold hinges after rotation of the G_1 axial planes to the horizontal about the local G_2 fold axis. (*c*) 64 G_2 fold hinges (contoured 1-5-10-15 points per 1% area) with a maximum plunging 12° at N20°. Poles of G_2 axial planes and transposition foliation are also shown. (*d*) Poles of G_3 hinges, axial planes and β-lineations on the transposition foliation.



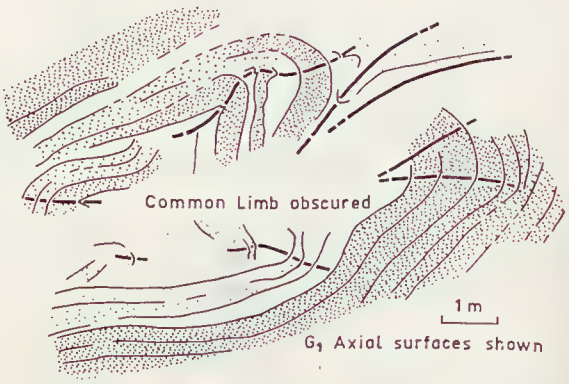
a.



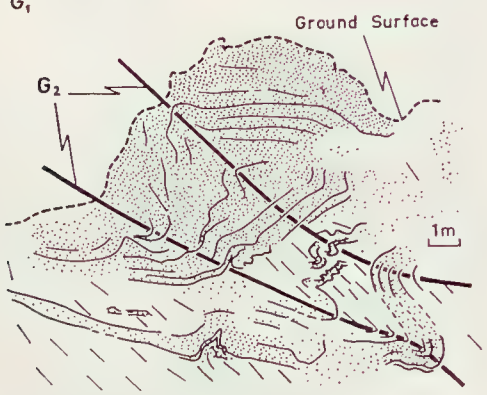
b.



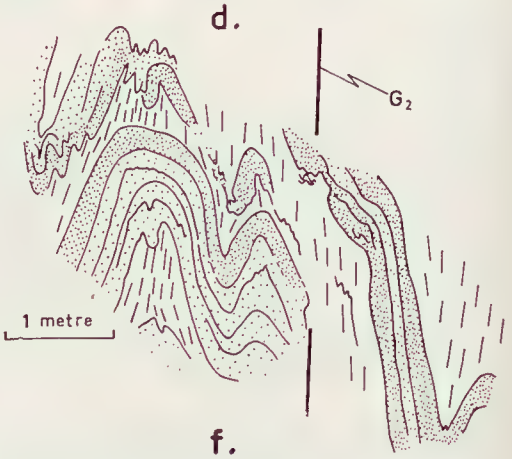
c.



d.



e.



f.

FIG. 3.—Fold profiles traced from photographs. The density of stippling is proportional to quartz %. Heavy stippling is 95% quartz; the unstippled areas are phyllite. Small dashes show traces of the G_2 cleavage. All profiles are oriented with east on the right, west on the left, and horizontal parallel to the base of the tracings. (*a*) G_1 folded by G_2. (*b*) Irregular, bulbous G_1 folds with curviplanar axial surfaces. (*c*) A larger-scale profile of the environs of the bulbous G_1 folds in (*b*). (*d*) Antiformal hinge of one of the larger-scale G_1 folds. (*e*) Large-scale quartzitic rod in the hinge of a G_2 fold in which the limbs are attenuated. (*f*) Common type of G_2 profile with transposition foliation well developed in the phyllite.

enveloping surfaces is congruous with the G_2 deformation being caused by an upwards overriding from the east—a sense of movement opposed to the movement inferred from the G_1 folds.

A foliation produced by the transposition of original psammitic and pelitic laminations in the phyllite is parallel to the axial surfaces of the G_2 folds. This transposition foliation is strongly developed in the most pelitic bands, and in parts almost obliterates the original laminations. Gravitational slip along the foliation causes some slope instability, and is a problem in engineering construction. Fortunately, the transposition foliation does not extend through quartzite layers thicker than 30 cms. Thin pelitic ribbons in the thinner quartzite layers are parallel to the G_2 axial surfaces, and cut the quartzite into slices producing a cleavage non-penetrative below the scale of mms.

Group 3 Folds

The third group, G_3, is characterized by tight, almost isoclinal folds with hinges pitching steeply in the transposition foliation. These folds are small-scale—wavelengths range from mms to dcms—and occur only in the phyllite. The profiles are almost ideally similar, but the few, thin, psammitic layers involved have the geometry of concentric folds flattened 40% to 50% perpendicular to the axial plane.

The G_3 axial planes (fig. 2*d*) dip steeply eastward as do the G_2 axial planes, but the G_3 axial planes diverge in strike by 10° to 20° in a clockwise sense from the G_2 axial planes. The sense of coupling indicated by the limbs of the G_3 folds corresponds to a subhorizontal movement of the eastern side southwards. Refolding involving G_2 structures is not common, but everywhere indicates that G_3 folds G_2. The considerable spread of the hinges in the mean axial plane (fig. 2*d*), as opposed to the more axial symmetry of G_1 and G_2, is characteristic of similar folding.

G_3 hinges are too small to measure directly in many places and are represented by a crenulation lineation. This β-lineation (fig. 2*d*) appears to be particularly useful for mapping as it is both widespread and easy to identify even in weathered outcrop, and it appears to have a consistent pitch of 50° to 60° to the north-northeast in the transposition foliation.

Kink Bands

Kink bands are common throughout the Precambrian rocks of Tasmania and are generally attributed to Palaeozoic deformation. In the vicinity of the Middle Gordon Damsite the kink bands occur mainly in the phyllite, and everywhere fold G_1, G_2 and G_3 structures. Orientations of kink bands have not been measured.

Interpretation

The style and orientation of G_1 is congruous with the hypothesis that the deformation represents considerable subhorizontal overriding of the western block towards the east. The bulbous, concentric style of the folds and the absence of well-developed cleavage indicate that this movement may have occurred early in the lithification history of the sediments.

G_2 reflects a steeply inclined thrusting of the eastern block towards the west. The penetrative, similar style of folding probably occurred in the low greenschist facies.

G_3 represents horizontal wrenching of the eastern block southwards within the phyllites. The similar style of folding and planar spread of fold hinges are consistent with the dominant mode of deformation being simple shear along the transposition foliation. G_1 may correlate with Spry's F_1 (1963), and G_2 with his F_2, but there are no conclusive data to justify such a correlation at present.

The manner in which successive deformations affect only certain zones is typical of sedimentary and low-grade metamorphic deformation in other areas (Gee, 1967, and Powell, 1967). Where such a pattern of deformation can be established orientational data can be interpreted without complex unrolling of early structures about later axes.

ACKNOWLEDGMENTS

The data in this paper were collected during July and August 1967, while I was contracting for the Hydro-Electric Commission of Tasmania, and I am indebted to Mr Knight, Commissioner, for permission to publish. I thank Mr G. Hale and his staff geologists for advice and help in the field.

REFERENCES

CORBETT, K. D., 1965—Middle Gordon Investigation. Geological investigation progress report 644-93-1 on the Knob Damsite. 15 pp.

GEE, R. D., 1963—Structure and petrology of the Raglan Range, Tasmania. *Bull. geol. Surv. Tasm.*, 47, 40 pp.

————, 1967—*The tectonic evolution of the Rocky Cape geanticline in northwest Tasmania.* Ph.D. thesis, Unpub. Tas. Univ., 351 pp.

POWELL, C. McA., 1967—*Studies in the geometry of folding and its mechanical interpretation.* Ph.D. thesis, Unpub. Tas. Univ., 282 pp.

RAMSAY, J. G., 1962—The geometry and mechanics of formation of "similar" type folds. *J. Geol.*, 70, pp. 309-327.

————, 1967—*Folding and fracturing of rocks.* New York, McGraw-Hill, 568 pp.

SPRY, A. H., 1967—Precambrian rocks of Tasmania, Part II. Mt Mary Area. *Pap. Roy. Soc. Tasm.*, 91, pp. 95-108.

————, 1962a—The Precambrian rocks. Pp. 107-126. *In* 'The Geology of Tasmania'. *J. geol. Soc. Aust.*, 9, pp. 107-362.

————, 1962b—*Some aspects of the stratigraphy structure and petrology of the Precambrian rocks of Tasmania.* Ph.D. thesis, Unpub. Tas. Univ., 317 pp.

————, 1963—The chronological analysis of crystallization and deformation of some Tasmanian Precambrian rocks. *J. geol. Soc. Aust.*, 10, pp. 193-208.

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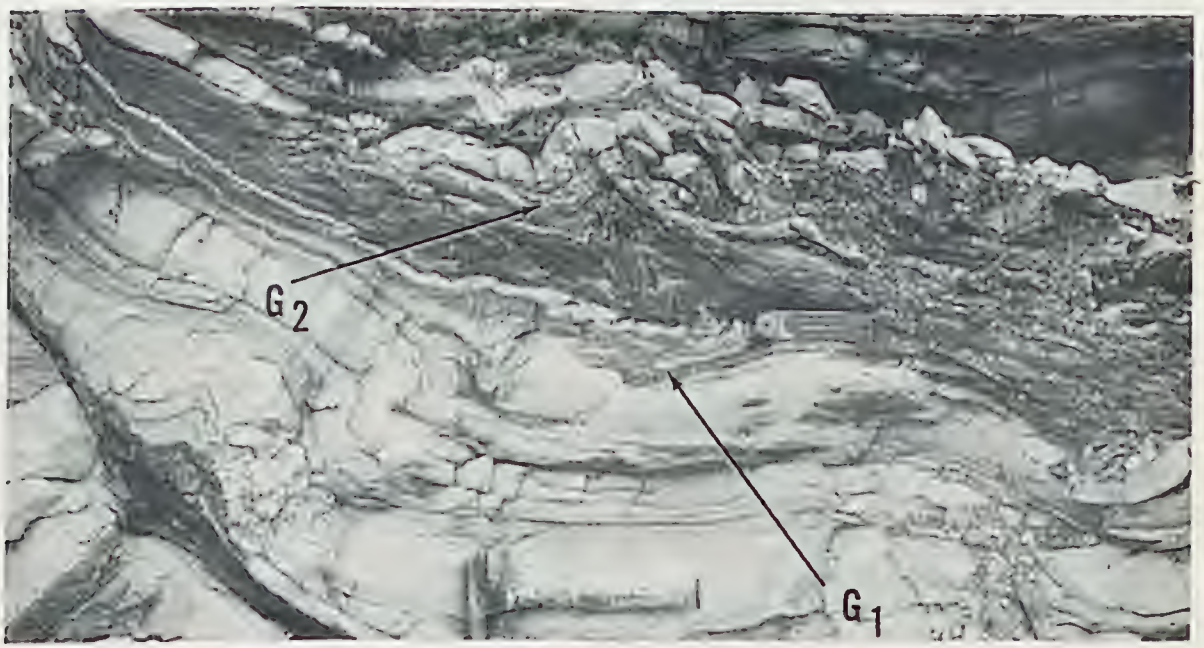
Plate 1

No. 1.—Almost vertical G_1 folds with curvilinear axial surfaces folded by right G_2 folds with planar axial surfaces.



No. 2.—G_2 folds which are well developed in phyllitic layers have not deformed the thicker quartzite bands in which there is a G_1 fold. Refolding occurs only near the hinge of the six-inch rule.

Both photographs are located in the road cut near the Middle Gordon Damsite meteorological station.

F.P.52

Papers and Proceedings of the Royal Society of Tasmania, Volume 103

NEW ZEALAND SEA STARS IN TASMANIA

By

A. J. Dartnall

The Tasmanian Museum, Hobart

(With two figures)

SUMMARY

Two species of sea stars, the asterinid *Patiriella regularis* (Verrill), 1867 and the asteriid *Astrostole scabra* (Hutton), 1872, hitherto known only from New Zealand, are recorded from Tasmania.

Attention is drawn to the probable mode of import of *Patiriella regularis* and supporting evidence given. *Patirella mimica* Livingstone, 1933 is regarded as synonomous with *P. regularis*.

A check list of the Tasmanian Asteroidea known to date is appended.

INTRODUCTION

Thirty-four species of Asteroidea are known from around Tasmania. Some fifteen genera and six species are common to the marine faunas of both Tasmania and New Zealand. The two species formally recorded below are new records for Tasmanian waters.

ASTERINIDAE

Patiriella regularis (Verrill), 1867

Patiriella regularis is known as one of the most common Asteroidea of the New Zealand littoral (Fell, 1959; Morton and Miller, 1968).

The discovery that *Patiriella regularis* is also one of the most common littoral and shallow water sea stars in S.E. Tasmania prompted some investigation of its distribution and origin in the area. Although its presence was inferred in a previous paper (Dartnall, in press) no explanation was mooted. *P. regularis* is confined, in Tasmania, to the waters enclosed by the Derwent Estuary; the D'Entrecasteaux Channel in the west and the western shore of the Tasman Peninsula in the east (fig. 1). So far, the animal is not known from the remainder of Tasmania.

Such a limited distribution of an animal which is so successful where it occurs (for example, it is one of the dominant members of the fauna of the Hobart wharves), poses a number of question about its origin.

Other animals of New Zealand origin are known from the area. McNeil and Ward (1930) recorded *Cancer novaezelandiae* (Jacquinot & Lucas), 1853; Lodder (1902) a brachiopod attributed to *Terebratula rubicunda* (≡ *Terebratula inconspicua* (Sowerby)); May (1923) *Amaurochiton glaucus* Gray, 1828 and *Mytilus canaliculus* Martyn, 1784. Greenhill (1965) recorded the presence of three species of molluscs of New Zealand origin in the D'Entrecasteaux Channel, *Maoricolpus roseus* (Quoy & Gaimard), 1834, *Paphirus largillierti* (Philippi), 1849 and *Neilo australis* (G. & G.), 1835. Recent work has also revealed *Halicarcinus inominatus* within the area (Lucas pers comm.).

H. L. Clark, visiting Hobart in 1929, did not record *Patiriella regularis* from the Derwent Estuary and May did not record *Maoricolpus roseus* when he dredged there in the 1920's. These two animals are now far too numerous not to be noticed by the serious collector and it may be assumed that they have been members of the marine fauna of S.E. Tasmania for less than forty years.

Fell (1962) has produced evidence for epiplanktonic dispersal of littoral echinoderms under the influence of the West Wind Drift, an orientation not complementary to the distribution observed. Man is the only agency which regularly opposes the West Wind Drift and the sporadic introduction of New Zealand oysters has been suggested as the source of the animals under consideration (McNeil and Ward 1930, Lodder 1902, May 1923).

Introductions of oysters, *Ostrea angasi* Sowerby, 1871, to bolster a failing industry and satisfy public demand are mentioned in the Fisheries Department Reports (1885, 1887) and the Report of the Sea Fisheries Board (1926-27). New Zealand oysters were imported for sale at the Hobart Fish Market, where they were kept alive in crates in the water, from about 1920 onwards. Commercial import of oysters from the Bluff, South Island, New Zealand continued into the 1930's, the oysters being carried as deck cargo aboard the ships operating the 'Horseshoe Run' which ran regularly between the Bluff and Hobart. Towards the end of the 1930's commercial import of oysters appears to have ceased, but the crews would carry oysters as deck cargo, shucking the oysters as the ship entered the Derwent Estuary and throwing the detritus overboard before the ship docked (Capt. D. I. Buckle, pers. comm.).

The New Zealand animals determined, so far, from the Tasmanian marine fauna are found in habitats ranging from the shore to offshore waters, on mud, on sand and on and amongst rocks. Oyster samples from beds covering or adjacent to all these habitats may have been the source of these animals.

It would appear logical that several waves of introductions took place. The brachiopod was certainly present by 1902, *Cancer novaezelandiae* by 1930 and *Patiriella regularis* not before 1930.

FIG. 1.—Map of S.E. Tasmania showing localities from which *Patiriella regularis* has been collected.

Comments

The asterinid genus *Patiriella* is represented in Australia by seven species. H. L. Clark (1946) expressed his doubts about the validity of *Patiriella mimica* Livingstone, 1933, known from one specimen taken from Newcastle Bight, N.S.W. After examination of the holotype of *P. mimica* (Australian Museum Reg. No. J1696) this author considers that the species should be relegated to the synonomy of *Patiriella regularis* (Verrill), 1867 as the specimen comes within the observed variation of that species.

Within S.E. Tasmania *P. regularis* has become a very successful member of the littoral and shallow water benthos and can be expected to extend its distribution around the coasts of Tasmania if its ubiquitous distribution around New Zealand is considered as a model.

ASTERIIDAE

Astrostole scabra (Hutton), 1872

The genus *Astrostole* is closely related to *Coscinasterias*, differentiation being based on the diplacanthid adambulacral spines of the former (H. L. Clark 1946). Six species are known from the Southern Hemisphere (A. M. Clark 1950) the Australian species being *Astrostole insularis* H. L. Clark, 1938 from Lord Howe Island.

Astrostole scabra is known from the S.E. and east coasts of Tasmania (see map) from the shore to c.30 metres. Reliable eye witness reports indicate that the species is probably also present on the west coast of Tasmania.

The smallest specimens obtained have R c.100 mm and the absence of juveniles throughout the year has led to some comment when compared with *Coscinasterias calamaria* whose juveniles (R = 20 < mm) are locally abundant between September and March of each year.

A. scabra, in Tasmania, has been observed feeding upon *Notohaliotis ruber* Leach, 1814, *Scutus antipodes* Montfort 1810 and *Argobuccinium vexillum* Sowerby, 1834. In aquaria this species captured and ingested *Pleurobranchus maculatus* (Quoy & Gaimard), 1822 and *Paragrapsus gaimardii* (Milne-Edwards), 1853.

CHECKLIST OF TASMANIAN ASTEROIDEA

Abbreviations indicate the source of information used to compile this check list.

A.M.—Collections of the Australian Museum, Sydney
A.M.C.—A. M. Clark 1953
B.—A. M. Clark 1962
H.L.C.—H. L. Clark 1946
K.—Koehler 1920
L.—Livingstone 1933
Q.V.M.—Collections Queen Victoria Museum, Launceston
T.M.—Collections Tasmanian Museum, Hobart

Class STELLEROIDEA

Subclass Asteroidea

Family LUIDIIDAE

1. *Luidia australiae* Doderlein, 1920— H.C.L.

Family ASTROPECTINIDAE

2. *Astropecten pectinatus* Sladen, 1883— B., T.M.

Family RADIASTERIDAE

3. *Radiaster gracilis* (H. L. Clark), 1916— K.

Family GONIASTERIDAE

4. *Mediaster australiensis* H. L. Clark, 1916— H.L.C.
5. *Nectria ocellata* Perrier, 1876— B., H.L.C., T.M.
6. *Pentagonaster dubeni* Gray, 1840— A.M.C., T.M.
7. *Tosia australis* Gray, 1840— T.M., L., A.M.C.
8. *Tosia australis forma astrologorum*— T.M.
9. *Tosia magnifica* (Müller & Troschel), 1842— L., H.L.C., T.M.
10. *Anthenea acuta* (Perrier), 1869— H.L.C.

Family OREASTERIDAE

11. *Asterodiscus truncatus* Coleman, 1911— T.M. (Dartnall 1968)

Family ASTEROPIDAE

12. *Petricia vernicina* (Lamarck), 1816— T.M.

Family OPHIDIASTERIDAE

13. *Austrofromia polypora* (H. L. Clark), 1916— H.L.C., B., T.M.
14. *Pseudophidiaster rhysus* H. L. Clark, 1916— H.L.C., B.

Family PORANIIDAE

15. *Marginaster* sp.— B.

Family ASTERINIDAE

16. *Asterina atyphoida* H. L. Clark, 1916— Q.V.M.
17. *Asterina inopinata* Livingstone, 1933— L.
18. *Asterina scobinata* Livingstone, 1933— L., H.L.C., T.M., Q.V.M.
19. *Patiriella calcar* (Lamarck), 1816— T.M.
20. *Patiriella regularis* (Verrill), 1867— T.M.
21. *Patiriella exigua* (Lamarck), 1816— T.M.
22. *Patiriella* n. sp. (in press)— T.M.
23. *Patiriella gunnii* (Gray), 1840— T.M.
24. *Patiriella brevispina* H. L. Clark, 1938— Q.V.M., A.M.
25. *Paranepanthia grandis* (H. L. Clark), 1928— L., T.M.

Family ECHINASTERIDAE

26. *Henricia* sp. *obesa* group— H.L.C., B.

FIG. 2.—Map of Tasmania to show stations at which *Astrostole scabra* has been taken.

Family SOLASTERIDAE

27. *Crossaster multispinus* H. L. Clark, 1916— H.L.C.

Family ASTERIIDAE

28. *Stylasterias reticulata* (H. L. Clark), 1916— H.L.C., B.
29. *Astrostole scabra* (Hutton), 1872— T.M.
30. *Coscinasterias calamaria* (Gray), 1840— T.M.
31. *Australiaster dubius* (H. L. Clark), 1909— H.L.C., B., T.M.
33. *Allostichaster polyplax* Müller & Troschel, 1844— H.L.C., B., T.M.
33. *Allostichaster Polyplax* (Müller & Troschel(, B., T.M.
34. *Uniophora sinusoida* Perrier, 1875— H.L.C., T.M.

ACKNOWLEDGMENTS

I wish particularly to thank Miss E. C. Pope of the Australian Museum, Sydney and Mr R. H. Green of the Queen Victoria Museum, Launceston for permission to examine the collections in their care; Mr D. Wolfe who brought the first specimens of *Astrostole scabra* to my notice and the many people who have collected material for me around the Tasmanian coastline.

REFERENCES

CLARK, A. M., 1950—A new species of Sea-Star from Norfolk Is. *Ann. Mag. Nat. Hist.* ser. 12, vol. 3, pp. 808-810.

———— 1953—Notes on Asteroids in the British Museum (Natural History). *Bull. Brit. Mus.* (Nat. Hist.). Zool. vol. 1, pp. 379-412.

———— 1962—Asteroidea. *B.A.N.Z. Antarctic Research Expedition Reports*—ser. B, vol. IX, pp. 98-102.

CLARK, H. L., 1946—The Echinoderm Fauna of Australia. *Carnegie Institution of Washington. Publication* 566.

DARTNALL, A. J., 1968—*Asterodiscus truncatus* (Coleman), 1911, a new record for Tasmanian waters. *Proc. Roy. Soc. Tasm.*, vol. 102, p. 23.

FELL, H. B., 1959—Starfishes of New Zealand, *Tuatara* vol. 7, pp. 127-142.

———— 1962—West Wind Drift Dispersal of Echinoderms in the Southern Hemisphere. *Nature*, vol. 193, pp. 759-161.

GREENHILL, J. F., 1965.—New Records of Marine Mollusca from Tasmania. *Proc. Roy. Soc. Tasm.*, vol. 99, pp. 67-69.

KOEHLER, R., 1920—Asteriés. *Australasian Antarctic Expedition*, 1911-14. *Sci. Rpt.* ser. C, vol. 8 (1).

LIVINGSTONE, A. A., 1933—Some Genera & Species of the Asterinidae. *Rec. Aust. Mus. Sydney*, vol. 19, pp. 1-18.

LODDER, M., 1902—The Recent Mollusca of Tasmania. In Handbook—*Aust. Ass. Adv. Sci.*, 9th Session, Hobart, pp. 89-93.

MAY, W. L., 1923—Revised J. Hope Macpherson 1958. *An Illustrated Index of Tasmanian Shells.* Tas. Govt Printer, Hobart.

MCNEIL, F. A. and WARD, M., 1930—Carcinological Notes. *Rec. Aust. Mus. Sydney*, vol. 17, pp. 357-383.

MORTON, J. and MILLER, M., 1968—*The New Zealand Sea Shore.* Collins, 638 pp.

PLEISTOCENE DEPOSITS AT PARANGANA DAMSITE IN THE MERSEY VALLEY–RESULTS OF EXCAVATION AND CONSTRUCTION DRILLING

By

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(With two text figures and four plates)

ABSTRACT

Pleistocene periglacial and glacial deposits exposed in the cut-off trench dug for Parangana Dam are described. The valley profile beneath the axis and downstream toe of the dam is discussed, and it is concluded that the dam lies in the terminal zone of the Mersey Valley Glacier.

INTRODUCTION

The following information is the result of excavation of the cut-off trench for Parangana Dam, and of drilling piezometer holes at the downstream toe of the dam. The results of investigation of the damsite were given in Volumes 99 and 100 of this journal.

Parangana Dam is situated ½ mile below the Fisher River Junction in the gorge tract of the Mersey River. At the damsite (fig. 1, pl. 1) the river is superimposed and flows across the structural trend in a wide gorge that has been cut in vertically to near vertically foliated Precambrian Fisher Group quartzite, schist, phyllite and slate. Investigation drilling and a seismic survey along the dam axis revealed a narrow buried U-shaped central channel 200+ feet deep and 200 feet wide filled with Pleistocene and periglacial solifluction material containing bands of fluvioglacial and possibly fluvial material and overlain by glacial drift.

Channel Filling

In order to construct a cut-off for the dam a trench was excavated into the Pleistocene deposits along the dam axis to a depth of 35 feet below the river bed. The information obtained from the trench is shown on section B-B1 of figure 2.

The bottom of the channel has not been located, but investigation drilling has shown that the bulk of the channel, from elevation 940 feet to 1125 feet (185 feet) is filled with periglacial solifluction material. That is, the channel was filled by a number of mass movement slides from the valley slopes when a glacier was in the near vicinity. The slides are thought to be the result of thawing of the surface talus layer in the summer months while the ground below remained frozen, so that the surface layer became saturated with water and flowed down the slope. The material accumulated at a time when the flow down the valley was probably greatly reduced, when precipitation remained in the upper reaches in the form of snow and ice. The characteristics of the deposit are those of a talus deposit, for it is unstratified and composed of material of local origin from the immediately adjacent valley walls and the material is angular, indicating little transport.

Along the dam axis, where the valley walls are formed by quartzite, the rock fragments (Drill Holes 5773, 5774, 5781, 5782, 5783, 5784 and 5791) consist mostly of angular pebbles, cobbles and boulders (up to 18 inches in diameter) of quartzite with minor schist in a yellowish to reddish-brown sandy-clay to clayey-sand matrix. Downstream, where the valley sides are formed by repetitions of quartzite and schist, the proportion of schist pebbles (Drill Holes 5767 and 5771) is markedly higher. In both areas the ratio of fragments to matrix averages about 60 : 40. The periglacial solifluction layer exposed in the cut-off trench on the left abutment of the damsite is shown on plate 4.

A distinctive reddish-brown clay occurs in the core from Drill Holes 5768 (82 feet-114 feet), 5772 (120 feet-125 feet) and 5784 (80 feet-97 feet). It is missing in Drill Hole 5782 which lies between Drill Holes 5768 and 5784. In this hole the clay is replaced by periglacial solifluction material containing a sand band (87 feet-91 feet), suggesting erosion of clay. The clay layer was probably deposited in a lake dammed by a solifluction slide.

Bands of fine to coarse-grained quartz, quartzite and schist sand and gravel, ranging up to 11 feet in thickness, occur within the solifluction deposit, and the distribution suggests that some may extend laterally over half the width of the channel. These sands were probably laid down under fluvioglacial conditions, that is, they are probably material of glacial origin transported a short distance by meltwater and redeposited. The number of distinctive sand and clay layers present suggests that at least five major periglacial solifluction slides took place. A layer of fluvioglacial sand that was deposited near the top of the periglacial solifluction deposit is shown on plate 2.

Glacial Drift

Investigation drilling showed that glacial drift covers the periglacial solifluction layer and extends up both sides of the valley. The maximum thickness was 30 feet in the cut-off trench, but a 20

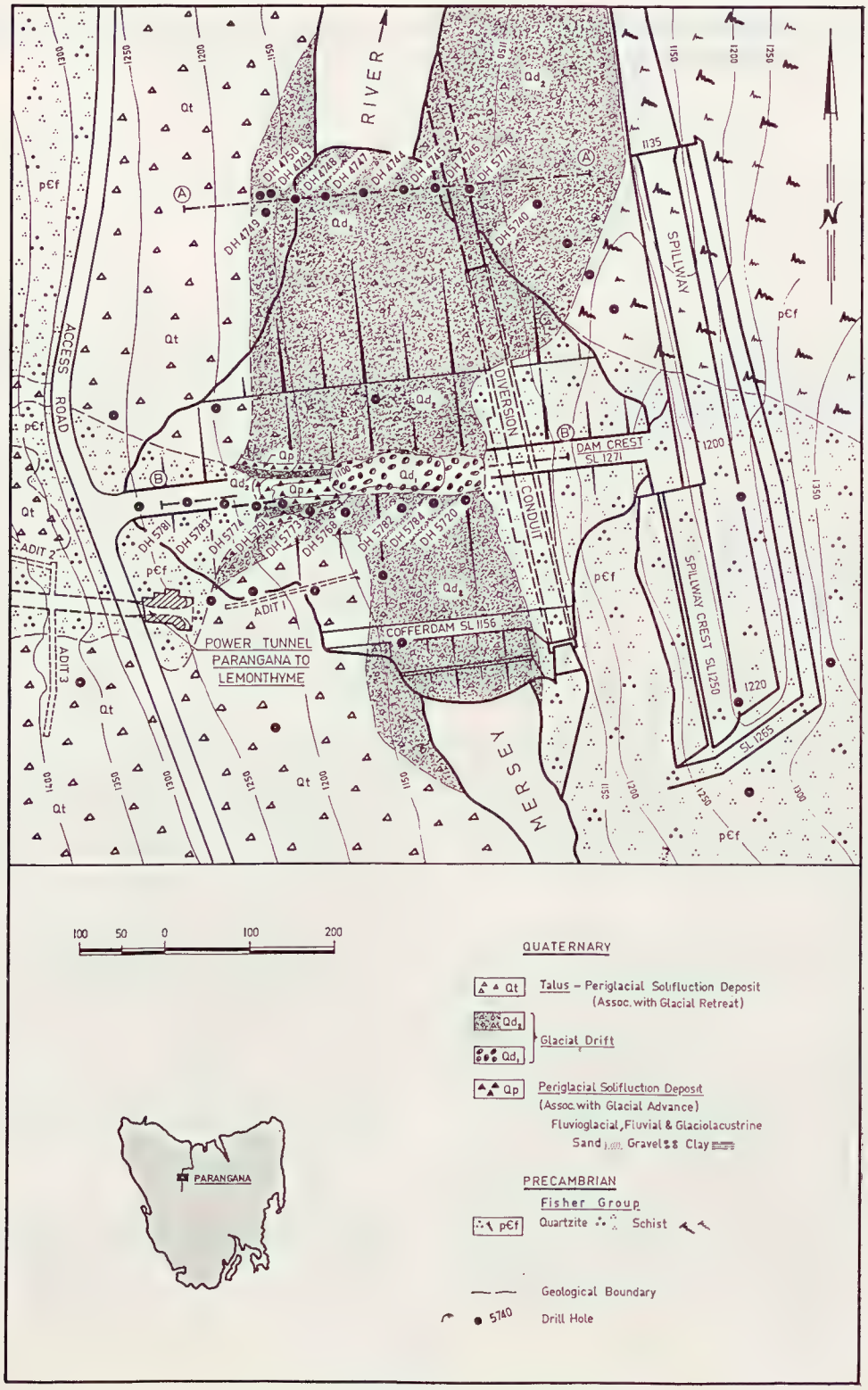

FIGURE 1.—Geological Map—Parangana Damsite.

feet thick deposit occurs on the right bank 150 feet above river level, and a 40 feet thick deposit occurs on the left bank 130 feet above river level.

The cut-off trench was taken below the base of the glacial drift layer into the periglacial solifluction layer. The material excavated agreed well with the section constructed from the investigation drilling with one exception. In the central part of the channel it was possible to recognise an early till in material that had been included in the periglacial solifluction deposit in the interpretation of the investigation drill holes. This till is composed of sub-rounded boulders, cobbles and pebbles of quartzite and sparsely scattered rounded dolerite boulders in a sandy-clay matrix. Seen in the face of the trench it was possible to distinguish it from the periglacial solifluction deposit by the roundness of the coarse material and by the presence of the dolerite boulders, but the layer could not readily be recognised in the drill holes, none of which encountered dolerite boulders in this zone.

The overlying younger till is distinguished by a predominance of dolerite boulders, cobbles and pebbles, with basalt, quartzite and schist contributing only minor amounts. The material is toughly compacted, uncemented to weakly cemented, unstratified and heterogeneous and up to 70% of the material consists of pebbles, cobbles and boulders coated with clay, silt and sand. Boulders of dolerite and basalt up to 7 feet in diameter occur and these are sub-rounded to rounded, whereas the boulders of quartzite and schist range up to 10 feet in diameter and are angular. The quartzite basalt and schist boulders are locally derived, possibly superglacial till, but the dolerite boulders have been transported from the Central Plateau. The till layer exposed in the cut-off trench is shown on plates 2, 3 and 4.

On the left abutment a pocket of periglacial solifluction material up to 90 feet wide and 30 feet deep occurs within the glacial drift (Drill Holes 5774, 5783 and 5791). This deposit was exposed in the walls of the cut-off trench and is shown on plate 3.

Talus

Talus originally obscured the greater part of the right abutment and all of the left abutment. Talus fans (pl. 1) extend almost to plateau level on both sides of the prominent quartzite cliffs that lie above the left abutment. The deposits have a maximum thickness of about 35 feet (Drill Hole 5719) and slopes of up to 30°. They consist of an upper few feet of loose rock fragments overlying lightly compacted, tough bony talus containing angular fragments of quartzite, schist and basalt set in a sandy-clay matrix. The junction of the talus with the underlying drift is a free draining zone coated with black carbonaceous material.

The upper loose layer is forming under the existing environment, but the thick compacted layer is considered to be the product of a periglacial environment and to have formed by solifluction as the glacier retreated from the site. It is stable under the existing environment.

Channel Profile

Examination of sections A-A_1 and B-B_1 (fig. 2), which were drawn along the dam axis and at the downstream toe of the dam respectively, show a notable change in valley profile within a distance of 320 feet. At the dam axis the profile drawn from drilling and seismic information suggests that the channel, which here was cut in quartzite, has been modified by glacial action, whereas at the downstream toe of the dam modification by glacial action appears lacking. Here in weaker schist a central high ridge was found with channels on both sides filled with periglacial solifluction material. The channel against the right bank is particularly narrow and V-shaped. This change in profile, together with the change from a straight broad valley with truncated spurs that exists upstream of the damsite to a narrow valley with interlocking spurs immediately downstream of the damsite, suggests that the dam is sited in the terminal zone of the Mersey Valley Glacier.

The situation suggests terminal moraine conditions such that both lodgement and ablation till might be expected. A degree of lithification corresponding to a weak tillite occurred in Drill Holes 5769 (47 feet-48 feet 6 inches), 5770 (27 feet-31 feet) and 5771 (16 feet-20 feet) suggesting deposition as a lodgement till under a considerable weight of ice. By comparison the glacial drift on the left abutment is only toughly compacted, and the high proportion of coarse material suggests some washing by meltwaters. The presence of a pocket of periglacial solifluction material within the till suggests a retreat and readvance of the glacier. A high proportion of rounded pebbles, cobbles and boulders occur in the till at Parangana. This may be the result of weathering of the dolerite in the source area, the distance of transport (up to 20 miles), and reworking in part by water during transport.

The degree of weathering of the glacial drift at Parangana is unusually deep, for in the adit on the left abutment the matrix was weathered yellowish-brown at a depth of 85 feet below the surface, which was 45 feet below the base of the talus. Deep weathering also occurs at the Fisher River Junction, where dolerite boulders are almost completely decomposed at a depth of 15 feet. By contrast the till in the Rowallan Dam borrow area 7 miles upstream is fresh a few feet from the surface. Weathered material may have been transported by ice to the Parangana area from the upper valley, but the difference in degree of weathering may also be indicative of an age difference between the two deposits, for the glacial drift at Parangana may be much older than the surface glacial drift at Rowallan damsite.

Summary of the Geomorphic History

The Mersey River took its present course (Spry, 1958) after extrusion of the Tertiary basalts, and at the beginning of the Pleistocene a valley about 1,600 feet deep was in existence. The nature of the basal deposits in the central channel is not known, but the profile at the dam axis suggests some modification by glacial action. By contrast the profile at the downstream toe of the dam is prominently fluvial. The central channel was

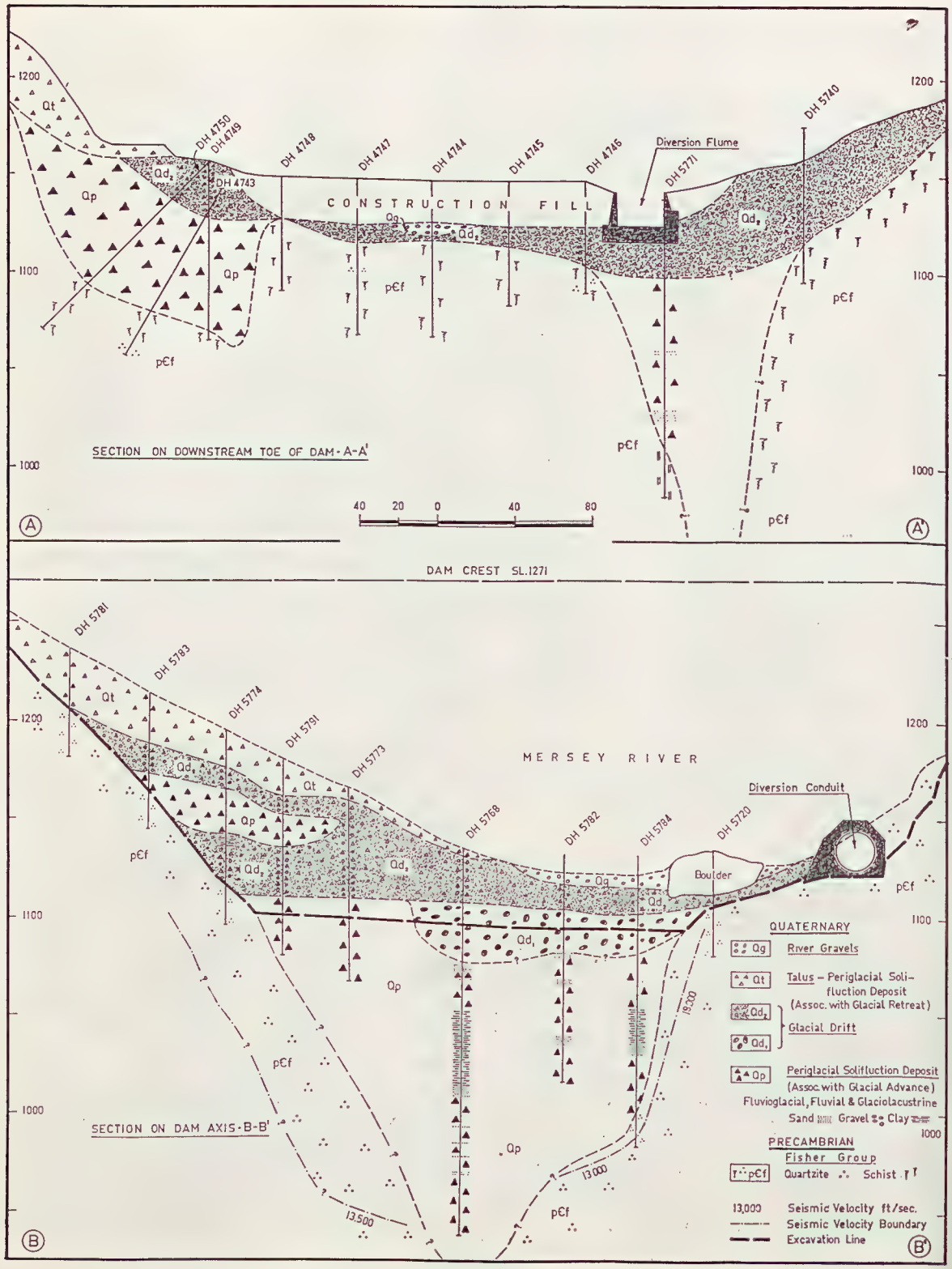
SECTION ON DOWNSTREAM TOE OF DAM - A-A'
CONSTRUCTION FILL
Diversion Flume
DH 4750
DH 4749
DH 4748
DH 4747
DH 4744
DH 4745
DH 4746
DH 5771
DH 5740
DH 4743
Qt
Qp
Qd2
Qd1
Qg
pCf
1200
1100
1000
40 20 0 40 80
A
A'
DAM CREST SL.1271
MERSEY RIVER
SECTION ON DAM AXIS - B-B'
DH 5781
DH 5783
DH 5774
DH 5791
DH 5773
DH 5768
DH 5782
DH 5784
DH 5720
Diversion Conduit
Boulder
19,000
13,000
13,500
B
B'
QUATERNARY
Qg River Gravels
Qt Talus – Periglacial Solifluction Deposit (Assoc. with Glacial Retreat)
Qd2 Glacial Drift
Qd1
Qp Periglacial Solifluction Deposit (Assoc. with Glacial Advance) Fluvioglacial, Fluvial & Glaciolacustrine
Sand Gravel Clay
PRECAMBRIAN
Fisher Group
pCf Quartzite Schist
13,000 Seismic Velocity ft/sec.
Seismic Velocity Boundary
Excavation Line

FIGURE 2.

filled by a series of solifluction slides while a glacier was in the near vicinity. During this period of reduced river flow the slides apparently effectively dammed the river permitting deposition of 32 feet (Drill Hole 5768) of clay. The sand and gravel bands present are thought to be fluvioglacial deposits laid down as the dams were overtopped. The presence of two distinctive tills and a pocket of periglacial solifluction material within the younger till suggests that at least three glacial advances occurred, at which time the solifluction deposits were protected from erosion by ground freezing. The dam is located within the terminal zone of the glacier.

ACKNOWLEDGMENTS

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Thanks are due to G. E. A. Hale, Chief Geologist of the Commission, and to G. Rawlings, formerly of the Commission, for helpful discussion.

The assistance of J. Ostwald in preparation of the figures is appreciated.

REFERENCES

PATERSON, S. J., 1965—Pleistocene Drift in the Mersey and Forth Valleys—Probability of Two Glacial Stages. *Pap. Roy. Soc. Tasm.*, 99, pp. 115-124.

———— 1966—Pleistocene Deposits at Parangana Damsite in the Mersey Valley. *Pap. Roy. Soc. Tasm.*, 100, pp. 147-151.

SPRY, A. H., 1958—Precambrian Rocks in Tasmania, Part III, Mersey-Forth Area. *Pap. Roy. Soc. Tasm.*, 92, pp. 117-137.

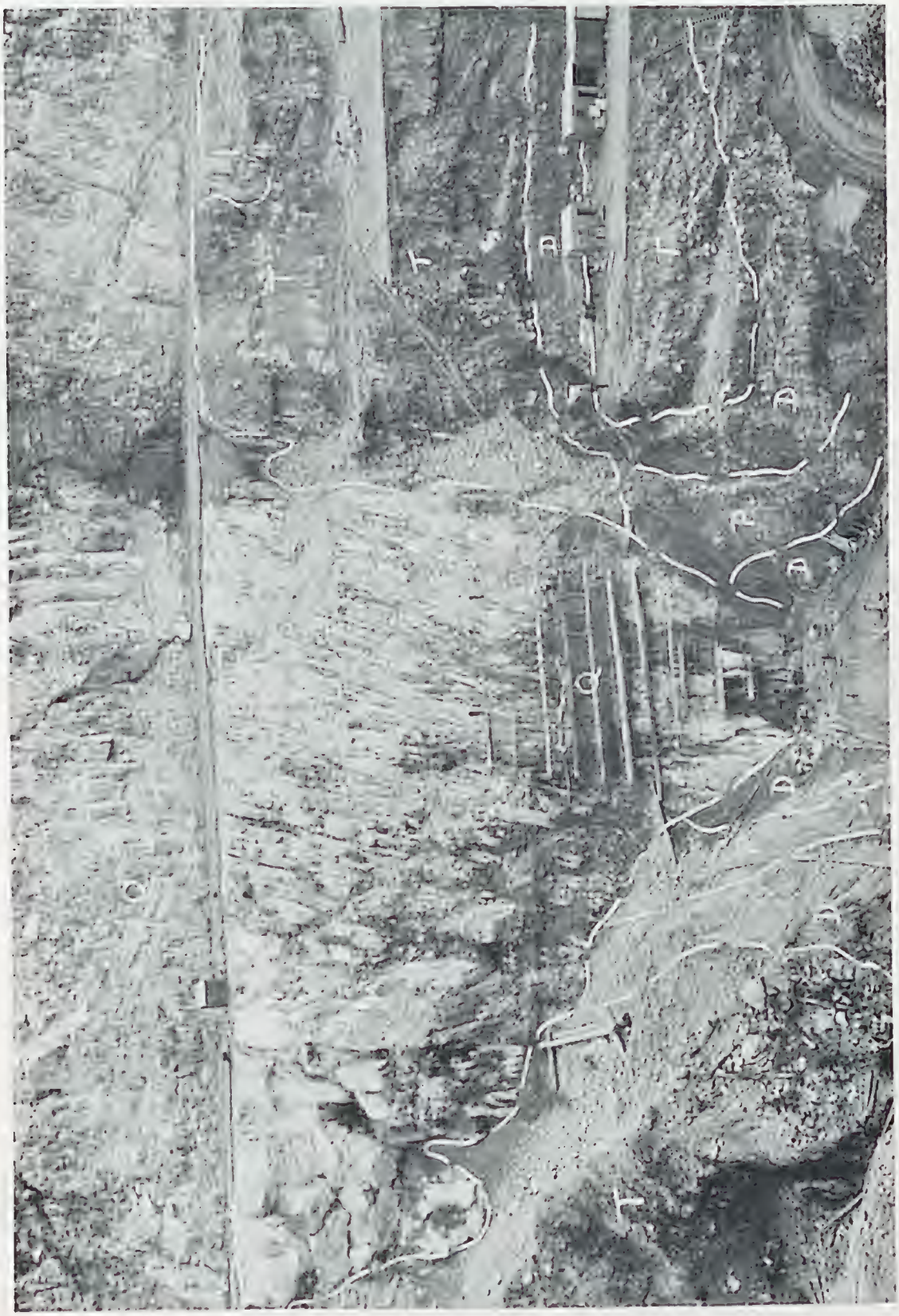

Plate 1.—The left abutment of Parangana Damsite after stripping of the overburden and excavation of the cut-off trench showing near vertically foliated Precambrian Fisher Group quartzite (Q), periglacial solifluction material (D), glacial drift (D) and talus (T).

Plate 2.—A fluvioglacial sand layer (F) at the base of the glacial drift (D) exposed in the upstream wall of the cut-off trench.

Plate 1.—A pocket of periglacial solifluction material (P) exposed within glacial drift (D) in the downstream wall of the cut-off trench. Note the angular nature of the quartzite fragments within the periglacial solifluction deposit and the roundness of the dolerite boulders in the glacial drift.

Plate 4.—The junction of the glacial drift (D) and periglacial solifluction material (P) in the downstream wall of the cut-off trench. Note the angular nature of the quartzite fragments in the periglacial solifluction deposit and the roundness of the dolerite boulders in the glacial drift.

ON PACHYPTERIS PINNATA (WALKOM) FROM TASMANIA

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(With three text figures)

ABSTRACT

Material from the Rhaetian of Tasmania referred to *Thinnfeldia pinnata* Walkom is described. The leaf is of thick substance, once pinnate, and probably abscissed. It shows a moderately thick cuticle with most stomata on the lower leaf surface, papillae over the stomatal pit, an unmodified leaf margin, and irregular subsidiary cells. With this information the leaf fits better in *Pachypteris* Brongniart than *Thinnfeldia* Ettingshausen, and is transferred to *Pachypteris*. It is readily distinguishable from other adequately known species of the genus.

INTRODUCTION

Although the great majority of fern-like but cutinised leaves from the Triassic floras of the Southern Hemisphere are forked, a few are known that are simple. Another instance is described herein, *Pachypteris pinnata* (Walkom) com. nov., a leaf that has been known for many years but not in detail.

Nothing is known of the reproductive structures of *P. pinnata*, but as with some other leaves, there are rather close similarities with unforked leaves to which are ascribed reproductive structures indicating that they belong to the Corystospermaceae (e.g., Harris 1964, Townrow 1963). Probably therefore *P. pinnata* belongs to this family also. It is not very easy to decide which genus of isolated leaf *P. pinnata* should go into, emphasising again the similarities between some of the pteridospermous leaves of the early Mesozoic, a similarity apparently extending to elements of the floras of both hemispheres.

The material was collected by one of us (J.A.T.) at the Valley Coal Mine, Fingal (now closed), a locality dated as Rhaetian on its megaspore content (Dettman 1961).

DESCRIPTION

?CORYSTOSPERMACEAE

PACHYPTERIS Brongniart

Pachypteris pinnata (Walkom) com. nov.

Figs. 1-3

?1888 *Pecopteris caudata* Johnston, pl. 26 fig. 6 only. Triassic of Longford, Tasmania.

1919 *Microphyllopteris pectinata* Walkom non Hector, pp. 186-187, pl. 8 figs 1, 4. Jurassic at Bexhill, New South Wales.

1921 *Thinnfeldia pinnata* Walkom, pp. 10-11, pl. 2 figs 1-4. Lower Jurassic at Talbragar, New South Wales.

1944 *Thinnfeldia praecordillerae* Frenguelli in part, pp. 511-519, pl. 1 fig. 1; pl. 3 fig. 1; pl. 4 fig. 3 (lower specimens, ?upper). Norinian, Cacheuta, the Argentine. (Excluded specimens having long pinnae, auricled at base.)

1967 *Thinnfeldia praecordillarae* Frenguelli: Jain and Delevoryas, p. 570, pl. 90, figs. 7, 8. Norinian, Cacheuta, the Argentine.

Excluded: 1950 *Thinnfeldia pinnata* Browne non Walkom. Pl. 40 *c*. Larger bipinnate leaf.

Holotype: Walkom 1921, pl. 2 fig. 1. Talbragar Fish Bed, Lower Jurassic.

Diagnosis emended. Once pinnate leaf, 6-12 cms long, 1-2 cms wide, narrow lanceolate in overall shape. Pinnae rounded, with very obtuse apex, entire margins and contracted at the base, or uncontracted, decurrent down the rachis to form a narrow laminae 1-2 mm wide flanking the rachis. Pinnae not displaced towards either surface of the rachis and only slightly, or not at all rotated to stand at an angle to the rachis.

Substance of pinnae thick, venation very obscurely shown on hand specimen, consisting of a midrib forking about half way along the pinnae, giving off simple, once or rarely twice forked laterals at about 30°. About 1 vein per 1 mm of margin.

Rachis not clearly marked off from the pinnae (probably) showing abscission scar at the base, channelled down the centre on both surfaces, as now compressed.

Cuticle about 2-3μ thick on upper (presumed adaxial) leaf surface, about half that thickness on under surface, showing slightly elongated or equidimensional polygonal cells lacking preferred orientation over lamina. At lamina edge cells elongated (about 25 x 40μ) forming 2 or 3 rows, but margin otherwise unspecialised, neither thickened nor scarious. Larger veins visible as rows of somewhat elongated cells on lower leaf surface only. Leaf amphistomatic, but most stomata lying on lower leaf surface (proportions about 30:1), between the veins, and without preferred orientation.

Cell outlines straight, or with only minute sinuousities, not pierced by holes, about 3μ wide. Stomata sunken in a pit formed by 5-8 subsidiary cells mostly lacking particular arrangements, but

a few (about 1 in 30) showing a more or less clear ring of small subsidiary cells; encircling cells absent or occasionally irregularly present. Stomata on lower leaf surface overhung by prominent hollow papillae borne on subsidiary cells, probably in life projecting upwards at a low angle, but on upper leaf surface papillae on subsidiary cells smaller or absent, being replaced by a collar of thick cutin. Cell surface with papillae or solid mounds of cutin about 5μ in diameter, such papillae occurring mainly on the upper leaf surface.

Rachis cuticle showing more or less rectangular or polygonal cells in vague longitudinal rows, and stomata like those on upper leaf surface. Stomata mainly on upper rachis surface (proportion about 4:3).

Locality of material studied: Valley Coal Mine, Fingal, Tasmania: Rhaetian.

Description: There are ten fragments available, none entirely complete but some (figs 1, 2) probably nearly so, all being very well preserved. The orientation of the specimens is not easy to decide. There are plainly two sorts of cuticle on the two surfaces, and it is assumed, by analogy with many living and fossil plants, that the stomatiferous one is the lower (abaxial). Of the hand specimens, one (fig. 2B) shows an incomplete leaf base, viewed from the lower surface, that is, not showing the abscission surface; and this leaf shows the veins fairly clearly. Other specimens (fig. 2A) do not show the veins (or only exceedingly obscurely), but do show in places slightly rotated pinnae, with the acroscopic edge of the leaf lying slightly lower than the basiscopic one. On the analogy of living plants with rotated pinnae, this means that we are looking at the upper (adaxial) leaf surface, and the failure to see the veins suggests the same.

Accepting this orientation, *both* surfaces of the rachis, as now compressed, are channelled, and where plant material is absent, show as a shallow trench (fig. 2A). The impression left by the pinnae is only a little less deep than that of the rachis. Presumably, therefore, the rachis was elliptical in section, scarcely thicker than the pinnae, and bore the pinnae laterally, and not displaced towards either surface. The circumstance that rachis and pinnae are only slightly different thicknesses, together with the obscurity of the veins suggests that the leaf was of thick substance, quite different, for example from *Dicroidium odontopteroides* (Morris) Gothan.

The existence of a leaf-base scar, noted also by Walkom (1921, p. 10) indicates, as he points out, that the leaf, like many leaves known to be corystocpermaceous, was shed entire. The single base is shown in figure 2c, and is incomplete, but seems to show a double scar, indicating that two traces entered the leaf (cf. Harris 1964, Townrow 1965). It is not possible to make out whether or where any such two traces joined, and it is possible that they continued independently far up the leaf, the channel down the centre of the rachis representing more compressible tissue between two traces. However, this is unknown, and the appearances can be explained other ways.

The veins were most easily seen by detaching pinnae, and macerating them in acid but not alkali, when they appear as dark strands, sometimes interrupted (fig. 2B). Apart from the elongated cells, the margin is seen to be unmodified both on the hand specimens, and cuticle preparations. However, a few pinnae are slightly convex downwards (i.e., the lower leaf surface concave as in *Gleichenia microphylla* for example).

The cuticle is readily prepared, and its features given in the diagnosis and in figures 3A-9. The papillae over the stomatal pit are borne more or less on the edge of the pit, and, as noted, vary in form, but always show an interior of lighter shade (fig. 3A) indicating that they are hollow; a feature also seen in some of the papillae on the epidermal cell surface (fig. 3D). In a number of instances, the tip of a papillae is at a slightly different plane of focus from its root, suggesting that before fossilisation the papillae may have pointed partly upwards. The guard cells are only thinly cutinised, and there is no sign of any cutin lining to the stomatal aperture.

Comparisons. Comparison of the present material is not easy because none of the other once pinnate leaves comparable with it have a cuticle, and all

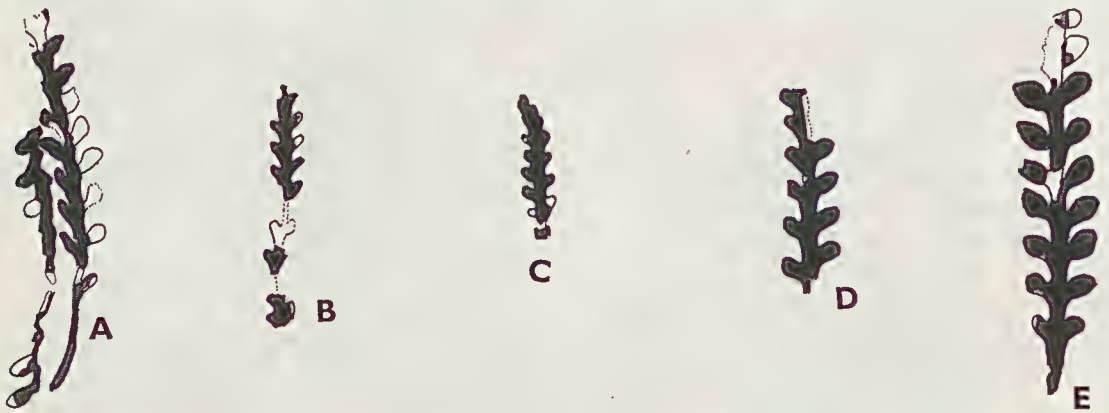

FIG. 1.—*Pachypteris pinnata*, A-E: Portions of leaves, A showing abscissed base, C an apex. ×1. University of Tasmania, Geology Department. 89775a,b; 89774; 89775d; 89776a; 89775c.

differ in gross form. The differences are, however, small, and in characters known to be inconstant where large populations of similar leaves are available. Under these circumstances it seems better to take a rather wide view, and place together for the time being leaves which may ultimately prove to be different. A group of badly known and scarcely distinguishable leaves is not convenient.

Thinnfeldia pinnata Walkom (1921) is a rather larger leaf than ours, with a rather more divided venation (these two features usually go together), but going on the figures, an equal vein density at the margin. The leaf bases are not contracted, but this feature varies in our material (figs 1D, E) and some of the leaves cited below come between. While noting the difference, we combine our material with Walkom's whose name takes priority. *T. pinnata* of Browne (1950) is a bipinnate and now referred to *Pachypteris crassa* (Halle) Townrow (1965).

Microphyllopteris pectinata of Walkom (1919) comes from Bexhill, N.S.W., and is from the Walloon Coal Measures of the Clarence Basin, approximately Middle Jurassic in age (McElroy 1962). Details of venation and cuticle are unavailable; in gross form this leaf does show slightly contracted pinnae, comparable with figure 2A and Walkom was almost certainly correct to identify it (1921) with *P. pinnata*.

Thinnfeldia praecordillerae Frenguelli in part (1944, see also Jain and Delevoryas 1967) is a leaf of size closely comparable to our material, of similar venation, and with slightly contracted pinna bases sometimes. Further detail is unavailable. It may differ in having slightly longer pinnae, but the difference is slight, and we believe inadequate for specific separation without more evidence.

Pecopteris caudata Johnson (1888 pl. 26 fig. 6 only) is doubtfully identical. The rather crude drawing does not give information enough for a definite opinion. The age is the same as our material.

At present *P. pinnata* ranges from the Norinian (Triassic) until approximately the Middle Jurassic, but in view of the uncertainties of all the identifications, this rather long range should not be given much weight.

Thinnfeldia dutoitii Jain and Delevoryas (1967) is definitely different however, showing odontopteroid venation, much like *Dicroidium feistmanteli*.

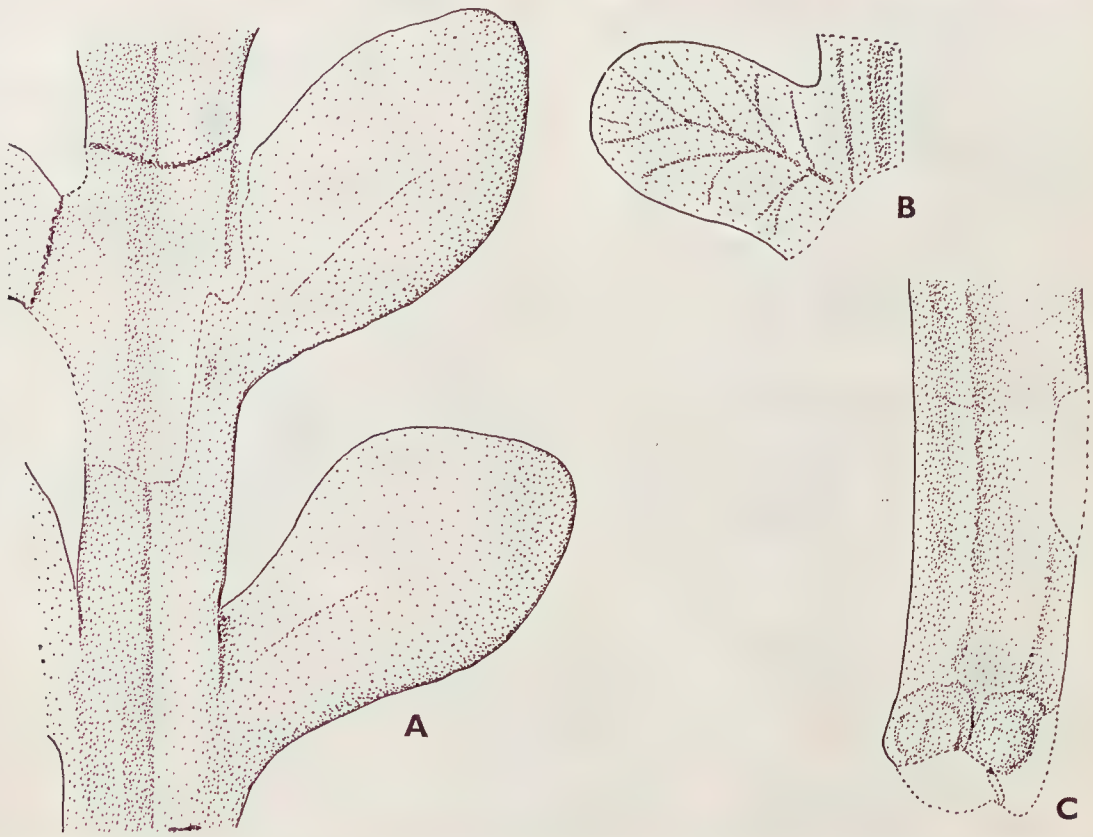

FIG. 2.—*Pachypteris pinnata*, A: Part of a leaf showing rachis as a trench both in the plant material and on the impression, slightly concave pinnae and obscure midrib. ×7. B: Pinna and veins. ×7. C: Leaf base with double abscission scar. ×11. University of Tasmania, Geology Department. A, 89775c; B, 89776a; C, 98775b.

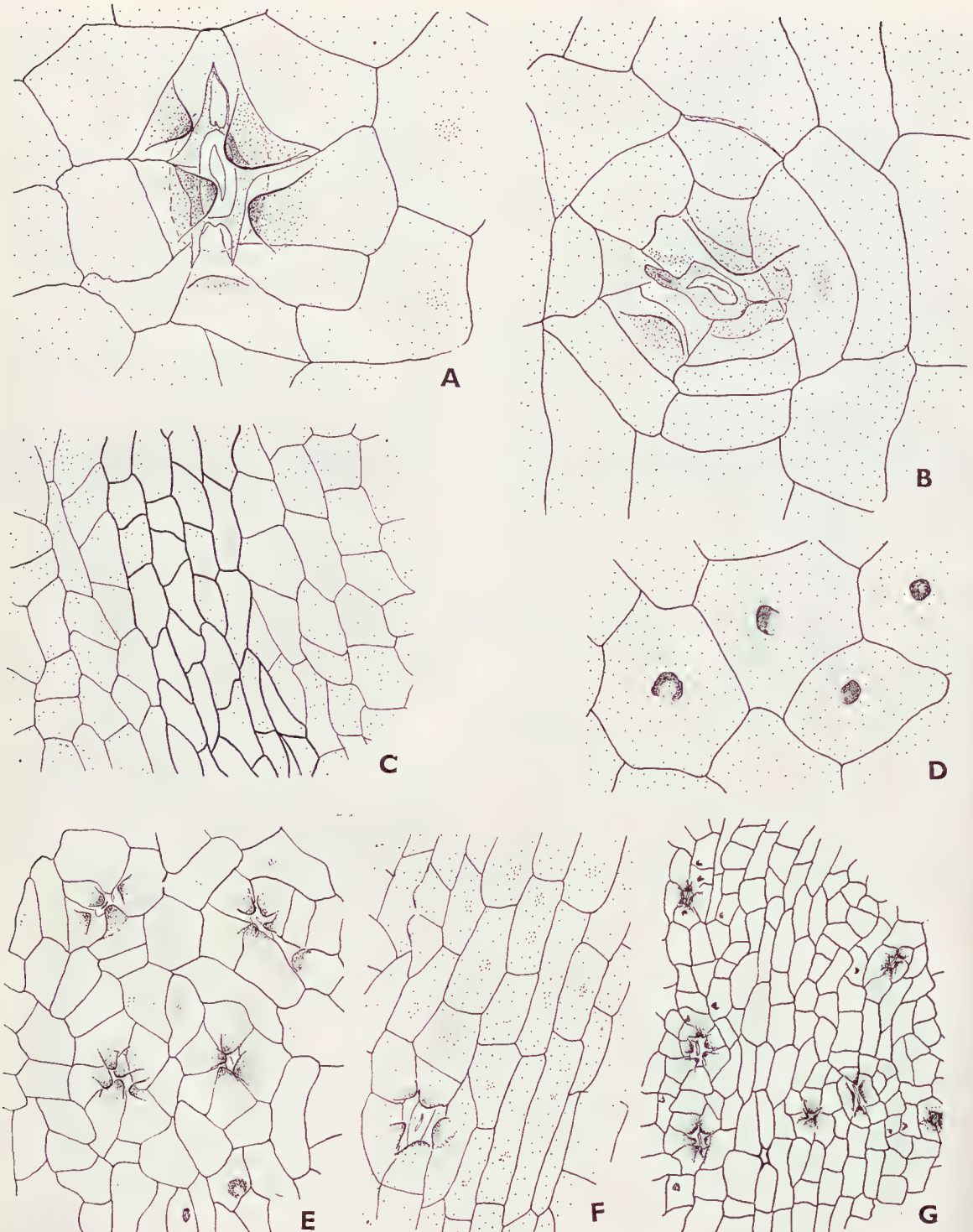

FIG. 3.—*Pachypteris pinnata*, A: Stoma with somewhat irregular monocyclic subsidiary cells. B: Stoma with rather regular dicyclic subsidiary cells. Both ×600. C: Cuticle along the margin (centre), ×200. D: Cells with small hollow papillae ×600. E: Cuticle from lower surface, away from a vein. ×200. F: Rachis cuticle. ×200. G: Cuticle over a vein (centre) and stomata. ×100. University of Tasmania, Geology Department. A,C,E, 89775a; B,D, 89775c; F, 89775c; G, 89774.

Fragments of *D. odontopteroides* could be confused with *P. pinnata*, but have a thin leaf substance and no papillae over their stomata, while *D. obtusifolium* has a thick leaf but scarcely sunken stomata in a rectangular pit, devoid of papillae (Townrow 1966). Other leaves probably would not cause serious confusion.

Generic Ascription. *P. pinnata* is excluded from *Dicroidium* (including *Xylopteris* Frenquelli and *Hoegia* Townrow) by being unforked (see Townrow 1957, and Bonetti 1966), from *Stenopteris* Saporta by having more than one vein per pinna, from *Lepidopteris* Schimper in lacking blisters on the rachis and in being once pinnate, and from *Cycadopteris* Zigno (including *Lomatopteris* Saporta) in lacking a thickened margin to the leaf (see Harris 1964 also Townrow and Hancock 1962). Of genera with a distinct midrib (that is excluding *Ctenozamites* Nathorst and *Dichopteris* Zigno) this leaves *Pachypteris* and *Thinnfeldia*.

The distinction between these two is not at all easy to draw (Harris 1964, Daber 1962, Barnard 1965). In general, however, species of *Thinnfeldia* have, or tend to have, distinct veins and a more or less regular circle of subsidiary cells, whereas *Pachypteris* has a thick to very thick leaf substance obscuring the veins, and rather irregular subsidiary cells. On this basis *P. pinnata* fits more easily into *Pachypteris*, agreeing with *P. papillosa* Thomas and Bos (Harris 1964) in being once pinnate, unlike the type species *P. lanceolata* Brongniart (Gomolitskiy, *et al.* 1962, Harris 1964). Like *P. papillosa*, *P. pinnata* also has papillae (mostly) over the stomatal pit but a much thinner cuticle. *P. pinnata* is also distinguishable from *P. crassa* (Halle) Townrow (1965) in being once pinnate, which also distinguishes it from the less well known *P. shemshakensis* Barnard (1965). Harris (*loc. cit.*) also discussed a number of poorly known leaves; or leaves of doubtful ascription to *Pachypteris*, which it is probably not worth discussing again at length here, except that we entirely agree with him that the forking specimens of du Toit should be excluded from *Pachypteris*.

At present, accepting the identification offered here, there are in the later Triassic and Jurassic gondwanan floras two reasonably well known unforked corystosperm (or probably corystosperm) leaves: *Pachypteris pinnata* and *P. crassa*. Both are more delicate leaves than the two somewhat younger well known European species, *P. lanceolata* and *P. papillosa*. In the case of *P. papillosa* and *P. crassa* the pollen organ is known, and though the pollen is similar, the organisation of the organs is rather different (Harris 1964, Townrow 1965), suggesting that though in the later Triassic and Jurassic the Corystospermaceae existed in both hemispheres, the component members remained somewhat different.

ACKNOWLEDGMENT

We are indebted to Mr J. Owens of the Valley Coal Mine for hospitality and help in collecting the material.

Works Quoted

Barnard, P. D. W., 1965—The geology of the Upper Djadjerud and Lar Valleys (North Iran). II. Palaeontology. *Riv. Ital. Palaeont.*, 71: 1123-1168.

Bonetti, M. I. R., 1966—Consideraciones sobre algunos representantes de la Familia 'Corystospermaceae'. *Ameghiana*, 4: 389-395.

Browne, W. R. *in* David, Sir T. W. Edgeworth, 1950—*The Geology of the Commonwealth of Australia* (1), xxx+747. London.

Daber, R., 1962—Blattreste im Lias von Nordöstdeutschland. *Paläont. Abh.*, 1: 123-138.

Dettmann, M. E., 1961—Lower Mesozoic megaspores from Tasmania and South Australia. *Micropalaeontol.*, 70: 71-93.

Frenguelli, J., 1944—Contribuciones al conocimiento de la flora del Gondwana Superior en la Argentina. xxv. *Thinnfeldia praecordillerae*. *Not. Mus. La Plata*, 9: 513-519.

Gomolitskiy, N. P., Kurbatov, V. V. and Sikstel, T. A., 1962—Novye materialyk kharakteristike roda *Pachypteris* (Paporotnikoobraznye). *Paleont. Zhurn.*, 2: 166-168.

Harris, T. M. 1964—*The Yorkshire Jurassic Flora II. Caytoniales, Cycadales and Pteridosperms*. *Brit. Mus. nat. hist.* viii+191. London.

Jain, R. K. and Delevoryas, T., 1967—A Middle Triassic flora from the Cacheuta Formation, Minas de Petroleo, Argentina. *Palaeontology*, 10: 564-589.

Johnston, R. M., 1888—*The Geology of Tasmania*, xxii+408. Govt Printer, Hobart.

McElroy, C. T., 1962—*The Geology of the Clarence-Moreton Basin*. xv+172. *Mem. geol. Surv. N.S.W.* 9.

Townrow, J. A., 1957—On *Dicroidium*, probably a pteridospermous leaf and other leaves now removed from this genus. *Trans. geol. Soc. S. Afr.*, 60: 21-56.

———— 1965—A new member of the Corystospermaceae Thomas. *Ann. Bot.* n.s. 29: 495-511.

———— 1966—On *Dicroidium odontopteroides* and *D. obtusifolium* in Tasmania. *Palaeobotanist*, 14: 128-136.

———— and Hancock, J., 1961—On *Cycadopteris anglica* Gothan. *Ann. Mag. nat. hist.* (13) 3: 297-303.

Walkom, A. B., 1919—On a collection of Jurassic plants from Bexhill, near Lismore, N.S.W. *Proc. Linn. Soc. N.S.W.* 44: 180-190

———— 1921—Mesozoic plants of New South Wales Part I.—Fossil plants from Cockabutta Mountain and Talbragar. *Mem. geol. surv. N.S.W., Palaeont.* 12: 121.

A SPECIES LIST OF AND KEYS TO THE GRASSES IN TASMANIA

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(With two text figures)

ABSTRACT

A dichotomising key is presented to facilitate the identification of the 190 species of the family Gramineae so far recorded for Tasmania. Brief notes of interest are included and the technical terms used are defined in diagrams and a short glossary. A second key to 70 species based on vegetative characters alone is included.

INTRODUCTION

No text on grasses present in Tasmania has been produced since the publication of Rodway's Tasmanian Flora of 1903, now obsolete and virtually unobtainable. The present species list has been compiled over a period of five years of general collecting by the author and students of the Faculty of Agricultural Science, University of Tasmania, and includes species found in that time whether native, introduced, wild or cultivated, in addition to a further dozen or more species recorded for Tasmania in the literature. Further additions are to be expected as detailed taxonomic studies are made of various difficult groups such as the Speargrasses (*Stipa* spp.).

Of the 190 species listed about 100 have been introduced since the arrival of the first white settlers, and of the 90 or so native species about 10 are thought to be *endemic* (*marked* '**E**' *in list*).

The majority of the native species occur in the following genera:—*Poa, Hierochloë, Amphibromus, Dichelachne, Deyeuxia, Agrostis, Danthonia* and *Stipa,* and are now mostly confined to agriculturally undisturbed heathland, and the more open parts of dry sclerophyll, in addition to mountain tops, where most of the probably endemic species such as *Danthonia pauciflora* occur. The species which are members of the *native flora are marked* '**n**'

Some of the species in the list are seldom found, either because they are rare indigenous grasses, or else are occasionally introduced weedy species or newly introduced species of agricultural value. *Rare grasses are indicated by the letter* '**R**' against the species number, and brief locality notes where known are given for the indigenous species amongst them.

The systematic arrangement of species in the list follows that used by J. H. Willis (1962), and the common names are largely taken from *Standardised Plant Names* C.S.I.R.O. Bull. No. 272. Those common names marked with an asterisk (*) are from J. H. Willis (1962) or C. E. Hubbard (1954).

The key to the species is based on characters which may be easily determined although a × 10 lens and a millimeter scale are necessary; technical terms have been avoided as much as possible. This key relies heavily on the keys to genera and species in J. H. Willis's 'A Handbook to Plants in Victoria' Vol. 1, in C. E. Hubbard's 'Grasses', C. A. Gardner's 'Flora of Western Australia', and in J. W. Vickery's various publications dealing with the Australian Species of *Danthonia, Agrostis* and *Deyeuxia* listed in the references. The key is composed of couplets or pairs of contrasting propositions each numbered consecutively with the alternative leads in each labelled (*a*) and (*b*). In a few instances more than two leads have been found convenient. Emphasis by means of italics is given to contrasting characters in the leads. The section (key numbers 126-132) dealing with the rather difficult genus *Stipa* (Speargrasses) is tentative, because the range of species in Tasmania and their identification is currently under study, and further additions and modifications are anticipated.

The key utilising vegetative characters only includes species mostly of agricultural significance, and will be of interest to those working with living plants in the field, when inflorescences are not available.

SPECIES LIST OF THE GRAMINEAE RECORDED IN TASMANIA[1]

Tribe		Common Name	Locality
1. *Ehrharteae*—			
R	1. *Ehrharta calycina* Sm.	Veldt grass, perennial	
n	2. *Microlaena stipoides* (Labill.) R. Br.	Weeping grass	
E n	3. *Microlaena tasmanica* H. & var. *subalpina* Rod.		
n	4. *Tetrarrhena acuminata* R. Br.	Ricegrass, pointed	
n	5. *Tetrarrhena distichophylla* (Labill.) R. Br.	Ricegrass, hairy	
n	6. *Tetrarrhena juncea* R. Br.	Ricegrass, wiry	
2. *Festuceae*—			
	7. *Briza maxima* L.	Quaking grass	
	8. *Briza minor* L.	Shivery grass	
	9. *Dactylis glomerata* L.	Cocksfoot	
n	10. *Puccinellia stricta* (Hook. f.) C. Blom	Marsh grass	
	11. *Catapodium rigidum* (L.) C. E. Hubbard	*Fern grass, rigid fescue	
n	12. *Distichlis distichophylla* (Labill.) Fassett	Saltgrass Australian	
n	13. *Poa poiformis* (Labill.) Druce	*Blue tussock grass	
n	14. *Poa labillardieri* Steud.	Tussockgrass, white	
n	15. *Poa tenera* F. Muell. ex Hook.	*Slender tussock grass	
R	16. *Poa compressa* L.	Bluegrass, Canada	
	17. *Poa pratensis* L.	Bluegrass, Kentucky	
n	18. *Poa saxicola* R. Br.	*Rock poa	
	19. *Poa annua* L.	Poa, annual/wintergrass/goosegrass	
	20. *Poa trivialis* L.	Meadow grass, rough-stalk	
R	21. *Poa bulbosa* L.	Poa, bulbous	
?E n	22. *Poa gunnii* (M. S. J. W. Vickery) also viviparous form		
n R	23. *Dryopoa dives* (F. Muell.) J. W. Vickery ≡ *Festuca dives* F. Muell.	*Giant mountain grass	Hills south of Kaoota. Snug Plains
n	24. *Festuca littoralis* Labill.	Fescue, coast	
n	25. *Festuca asperula* J. W. Vickery	Fescue, graceful	
	26. *Festuca rubra* L.	Fescue, red	
n	27. *Festuca hookeriana* F. Muell. ex Hook.	Fescue, Hooker's	
	28. *Festuca arundinacea* Schreb.	Fescue, tall	
n R	29. *Festuca plebeia* R. Br.		Table Mountain near R. Derwent; Mt Stuart
	30. *Vulpia bromoides* (L.) S. F. Gray	*Squirrel-tail fescue	
	31. *Vulpia myuros* (L.) K. C. Gmel.	*Rat's-tail fescue	
	32. *Vulpia megalura* (Nutt.) Rydb.	*Fox-tail fescue	
R	33. *Lolium temulentum* L.	Darnel	
	34. *Lolium perenne* L.	Ryegrass, perennial	
	35. *Lolium multiflorum* Lam.	Ryegrass, Italian	
	36. *Lolium rigidum* Gaudin	Rygrass, Wimmera	
	37. *Lolium loliaceum* (Bory & Chaub.) Hand.-Mazz.	Ryegrass, rigid	
	38. *Cynosurus echinatus* L.	Dogstail, rough	
	39. *Cynosurus cristatus* L.	Dogstail, crested	
3. *Glycerieae*—			
n	40. *Glyceria australia* C. E. Hubbard	*Australian Sweet-grass	
	41. *Glyceria maxima* (Hartm.) Holmb.	Meadow grass, water	
	42. *Glyceria declinata* Breb.	*Glaucous Sweet-grass	

[1] E = endemic n = native R = rare * = Common name from Hubbard (1954) or Willis (1962)

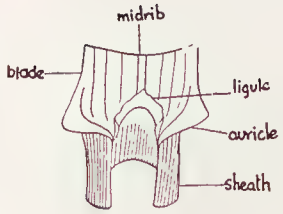
Tribe		Common Name	Locality
4. *Bromeae*—			
	43. *Bromus unioloides* (Willd.) Humb.	Prairie grass	
	44. *Bromus cebadilla* Steud.	*Chilean Brome	
	45. *Bromus mollis* L.	Brome, soft	
	45A. *Bromus thominii* Hard.		
	46. *Bromus sterilis* L.	Brome, sterile	
	47. *Bromus diandrus* Roth.	Brome, great	
	48. *Bromus madritensis* L.	Brome, Madrid	
	49. *Bromus macrostachys* Desf.	Brome, Mediterranean	
4a. *Brachypodieae*—			
R	50. *Brachypodium distachyum* (L.) Beauv.	Brome, false	
5. *Hordeeae*—			
n	51. *Agropyron scabrum* (Labill.) Beauv.	Wheatgrass, common	
	52. *Agropyron repens* (L.) Beauv.	Couch, English	
R	53. *Agropyron junceum* (L.) Beauv.	*Sea Wheat-grass Sea couch	
n R	54. *Agropyron velutinum* Nees	Wheatgrass, velvet	Alpine and subalpine grassland above 4000 feet
n	55. *Agropyron pectinatum* (Labill.) Beauv.	Wheatgrass, comb	
	56. *Triticum aestivum* L.	Wheat	
	57. *Secale cereale* L.	Rye	
	58. *Hordeum vulgare* L.	*6-row Barley	
	59. *Hordeum distichon* Hook.	*2-row Barley	
	60. *Hordeum leporinum* Link	Barley grass	
	61. *Hordeum marinum* Huds.	Barley grass, sea	
	62. *Hordeum hystrix* Roth	*Barley grass, Mediterranean	
6. *Monermeae*—			
	63. *Monerma cylindrica* (Willd.) Coss. & Durieu	Barb grass, common	
	64. *Parapholis incurva* (L.) C. E. Hubbard (1946)	Barb grass, coast	
7. *Aveneae*—			
	65. *Avena sativa* L.	Oat, common	
	66. *Avena fatua* L.	Oat, wild	
R	67. *Avena alba* Vahl	*Bearded oat	
R	68. *Avena strigosa* Schreb.	*Bristle oat	
n R	69. *Amphibromus archeri* (Hook. f.) P. F. Morris	*Pointed Swamp Wallaby grass	Roadside Exeter
n	70. *Amphibromus neesii* Steud.	Wallaby grass, swamp	
n R	71. *Amphibromus recurvatus* J. R. Swallen	*Dark Swamp Wallaby grass	Swampy ground near Bruny Island airstrip, Mt Field Nat. Park
	72. *Arrhenatherum elatius* (L.) J. & C. Presl and var. *bulbosum* (Willd.) Spen	Oatgrass, false *Onion couch/ Bulbous oatgrass	
R	73. *Koeleria phleoides* (Vill.) Pers.	Catstail, annual	
R	74. *Koeleria cristata* Pers.	Catstail, crested	
R	75. *Trisetum spicatum* (L.) Richt.	Bristle grass	
R	76. *Deschampsia caesipitosa* (L.) Beauv.	Hair grass, tufted	
	77. *Aira caryophyllea* L.	Hair grass, silvery	
	78. *Aira praecox* L.	Hair grass, early	
	79. *Aira elegans* Willd. ex Gaudin.		
	80. *Holcus lanatus* L.	Fog, Yorkshire	
n	81. *Hierochloë redolens* (Soland. ex Vahl) Roem. & Schult.	Holygrass, sweet	
n R	82. *Hierochloë rariflora* Hook.	Holygrass, scented	Mountain tops. Waratah N.W. Coast
?E n	83. *Hierochloë fraseri* Hook.		
	84. *Anthoxanthum odoratum* L.	Vernalgrass, sweet-scented	

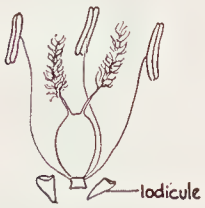
	Tribe		Common Name	Locality
8. *Phalarideae*—				
		85. *Phalaris arundinacea* L. and *var. picta* L.	Canary grass, reed *Ribbon grass	
		86. *Phalaris minor* Retz.	Canary grass, lesser	
		87. *Phalaris tuberosa* L.	Phalaris/Toowoomba canary grass	
	R	88. *Phalaris canariensis* L.	Canary grass	
	R	89. *Phalaris coerulescens* Desf.		
9. *Agrostideae*—				
		90. *Ammophila arenaria* (L.) Link	Marram grass	
	n	91. *Dichelachne crinita* (L.f.) Hook.	Plumegrass, long-hair	
	n	92. *Dichelachne sciurea* (R. Br.) Hook.	Plumegrass, short-hair	
E	n R	93. *Dichelachne sieberiana* Trin.		Mt Roland
	n R	94. *Dichelachne rara* R. Br.		Lune River, Bruny Is., Lyell Highway Mt Arrow-Smith
	n R	95. *Deyeuxia gunniana* (Nees) Benth.		Blakes Opening, Huon Rd, Zeehan
	n R	96. *Deyeuxia brachyathera* (Stapf) J. W. Vickery		Thomas Plains (Rodway)
	n	97. *Deyeuxia quadriseta* (Labill.) Benth.	Bent grass, reed	
	n	98. *Deyeuxia monticola* (Roem & Schult.) J. W. Vickery		
E	n R	99. *Deyeuxia accedens* J. W. Vickery		Fern Tree, Mt Wellington; towards Arthurs Lakes
	n	100. *Deyeuxia densa* Benth.		
	n R	101. *Deyeuxia carinata* J. W. Vickery		Mt Mawson, Mt Field Nat. Park
	n	102. *Deyeuxia minor* F. Muell. ex Benth.		
E	n	103. *Deyeuxia rodwayi* J. W. Vickery		
	n R	104. *Deyeuxia benthamiana* J. W. Vickery		Huon Rd & Mt Wellington
	n R	105. *Deyeuxia scaberula* J. W. Vickery		Base Mt Wellington, Huon Rd
	n	106. *Deyeuxia contracta* (F. Muell. ex Hook. f.) J. W. Vickery		
	n R	107. *Deyeuxia parviseta* J. W. Vickery		Mt Mawson, Mt Field Nat. Park
E	n R	108. *Deyeuxia lawrencei*, J. W. Vickery		
	n R	109. *Agrostis rudis* Roem. & Schult.	*Bent	Adventure Bay in swamp, Trial Harbour
	n R	110. *Agrostis hiemalis* (Walt.) Britton, *et al.*	Bent, winter	Dromedary Swamp (Rodway)
		111. *Agrostis stolonifera* L.	Bent, creeping	
		112. *Agrostis tenuis* Sibth.	Bent, browntop	
	R	113. *Agrostis gigantea* Roth	Bent, redtop	
	n R	114. *Agrostis muelleriana* J. W. Vickery	Bent, Muellers'	Smithies' Flats The Lakes
	n	115. *Agrostis parviflora* R. Br.	Bent, hair	
	n R	116. *Agrostis australiensis* Mez	Bent, Australian	Mt Wellington
	n	117. *Agrostis venusta* Trin.	Bent, graceful	
	n	118. *Agrostis billardieri* R. Br. + vars. *filifolia* & *robusta* J. W. Vickery	Blown grass, coastal	
	n	119. *Agrostis aemula* R. Br.	Blown grass	
	n	120. *Agrostis avenacea* J. F. Gmel.	Blown grass	
	n R	121. *Agrostis aequata* Nees		
		122. *Agrostis semiverticillata* (Frosk.) C. Ch.	*Water bent	
		123. *Polypogon monspeliensis* (L.) Desf.	Beardgrass, annual	
		124. *Polypogon maritimus* Willd.	*Coast Beard-grass	

Tribe			Common Name	Locality
		125. *Polypogon littoralis* Sm.	*Perennial Beard-grass	
		126. *Gastridium ventricosum* (Gouan) Schinz & Thell.	Nitgrass	
		127. *Lagurus ovatus* L.	Harestail grass	
		128. *Phleum pratense* L.	Timothy grass	
	R	129. *Alopecurus geniculatus* L.	Foxtail, marsh	
		130. *Alopecurus pratensis* L.	Foxtail, meadow	
		131. *Alopecurus myosuroides* Huds.	Foxtail, slender	
	n	132. *Echinopogon ovatus* (Forst. f.) Beauv.	Hedgehog grass, forest	
	n	133. *Pentapogon quadrifidus* (Labill.) Baill.	Speargrass, five-awn	
10. *Zoisieae*—				
	R	134. *Zoisia macrantha* Desv.	*Prickly Couch	Bass Strait Islands
	R	135. *Zoisia matrella* (L.) E. D. Merrill		
11. *Eragrostideae*—				
	n	136. *Eragrostis brownii* Nees ex Steud.	Lovegrass, Brown's	
		137. *Eragrostis cilianensis* (All.) Link ex Lut.	Stink grass	
12. *Chlorideae*—				
		138. *Cynodon dactylon* (L.) Pers.	Couch	
13. *Spartineae*—				
		139. *Spartina townsendii* H. & J. Groves	*Townsend's Cord-grass	
14. *Sporoboleae*—				
		140. *Sporobolus capensis* Kunth	Paramatta grass	
		141. *Sporobolus virginicus* (L.) Kunth	Couch, sand	
15. *Nardeae*—				
	R	142. *Nardus stricta* L.	*Mat-grass	
16. *Arundineae*—				
		143. *Phragmites communis* Trin.	Reed, common	
		144. *Cortaderia selloana* (Schult.) Aschers. & Graebn.	*Pampas grass	
17. *Danthonieae*—				
	n R	145. *Danthonia carphoides* F. Muell. ex Benth. and var. *angustior* J. W. Vickery	Wallaby grass, short	Cataract Gorge Domain Hobart
	n	146. *Danthonia semiannularis* (Labill.) R. Br. and var. *gracilis* Hook f.	Wallaby grass, Tasmanian	
	n R	147. *Danthonia longifolia* R. Br.	*Long-leaf Wallaby grass	
	E n R	148. *Danthonia pauciflora*	*Alpine Wallaby grass	Mt Mawson, Great Lake
	n	149. *Danthonia purpurascens* J. W. Vickery	*Wallaby grass	
	n	150. *Danthonia setacea* R. Br.	Wallaby grass, smallflower	
	n	151. *Danthonia caespitosa* Gaud.	Wallaby grass, ringed	
	n	152. *Danthonia procera* J. W. Vickery	*Tall Wallaby grass	
	n R	153. *Danthonia eriantha* Lindl.		
	n	154. *Danthonia laevis* J. W. Vickery		
	n	155. *Danthonia pilosa* R. Br.	Wallaby grass, smoothflower	
	n	156. *Danthonia penicillata* (Labill.) Beauv.	Wallaby grass, slender	
	n	157. *Danthonia racemosa* R. Br.		
	n R	158. *Danthonia nudiflora* P. F. Morris	*Alpine Wallaby grass	High alpine—Ben Lomond, Cradle Mt
	n R	159. *Danthonia nivicola* J. W. Vickery	*Snow Wallaby grass	Mt Rufus, Great Lake
	E n	160. *Danthonia dimidiata* J. W. Vickery		
	E n R	161. *Danthonia* sp. (undescribed)		Mt Mawson
	R	162. *Sieglingia decumbens* (L.) Bernh.	*Heath grass	

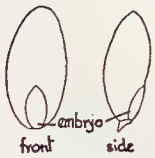
Tribe			Common Name	Locality
18. *Stipeae*—				
	n	163. *Stipa teretifolia* Steud.	*Coast Spear grass	
	n	164. *Stipa semibarbata* R. Br.	Speargrass, fibrous	
	n	165. *Stipa variabilis* D. K. Hughes	Speargrass, variable	
	n	166. *Stipa compacta* D. K. Hughes		
	n	167. *Stipa elatior* (Benth) D. K. Hughes		
	n	168. *Stipa nervosa* J. W. Vickery		
	n	169. *Stipa pubescens* R. Br.	Speargrass, tall	
E	n	and var. *aphylla* Rod.		
	n	170. *Stipa aphanoneura* D. K. Hughes		
E	n	171. *Stipa stuposa* D. K. Hughes		
	n	172. *Stipa eremophila* Reader		
	R	173. *Nassella trichotoma* (Nees) Hack.	Tussock, serrated	
		174. *Oryzopsis miliacea* (L.) Benth.	Millet, rice	
19. *Paniceae*—				
		175. *Panicum miliaceum* L.	Panic, millet	
	R	176. *Paspalidium gracile* (R. Br.) D. K. Hughes	Panic, slender	
		177. *Echinochloa crus-galli* (L.) Beauv.	Millet, Barnyard	
		and var. *frumentacea* (Link) W. F. Wright	Millet, Japanese	
		178. *Digitaria sanguinalis* (L.) Scop.	Summer grass	
		179. *Paspalum distichum* L.	Couch, water	
		180. *Paspalum dilatatum* Poir	Paspalum	
		181. *Setaria verticillata* (L.) Beauv.	Pigeon grass, whorled	
		182. *Setaria viridis* (L.) Beauv.	Pigeon grass, green	
		183. *Pennisetum clandestinum* Hochst. ex Chiov.	Kikuyu grass	
	R	184. *Pennisetum macrourum* Trin.	Feathergrass, African	
	R	185. *Pennisetum villosum* R. Br.	Feathertop	Bass Strait Islands
		186. *Stenotaphrum secundatum* (Walt.) Kuntze	Buffalo grass	
	n	187. *Spinifex hirsutus* Labill.	Spinifex, hairy	
20. *Andropogoneae*—				
	n	188. *Hemarthria uncinata* R. Br.	Mat grass	
		189. *Imperata cylindrica* (L.) Beauv.	Blady grass, kunai, Langalang	
	n	190. *Themeda australis* (R. Br.) Stapf	Kangaroo grass	
21. *Maydeae*—				
		191. *Zea mays* L.	Maize	

GENERAL STRUCTURE OF A GRASS





PISTIL & STAMENS



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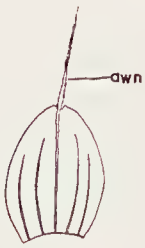

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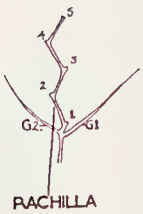
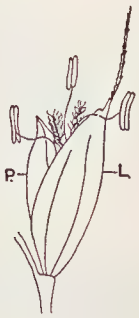


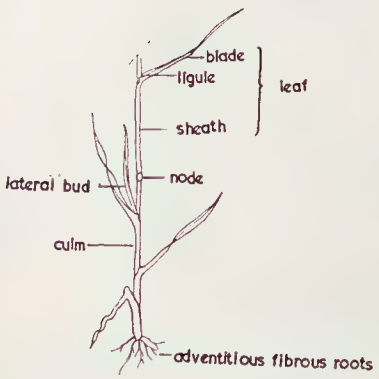
RACHILLA

G 1.
LOWER GLUME

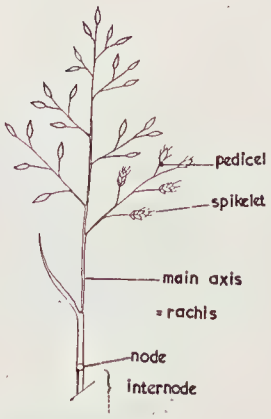
G 2.
UPPER GLUME



FLORET

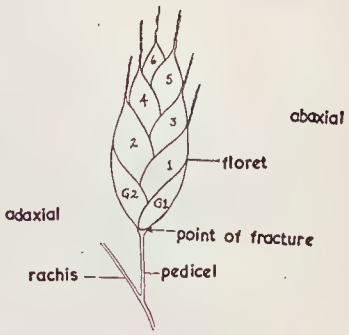


VEGETATIVE PARTS



INFLORESCENCE

WHOLE PLANT



SPIKELET

FIG. 1

A SPIKELET of DEYEUXIA ACCEDENS J.W. Vickery.
"Bent grass"

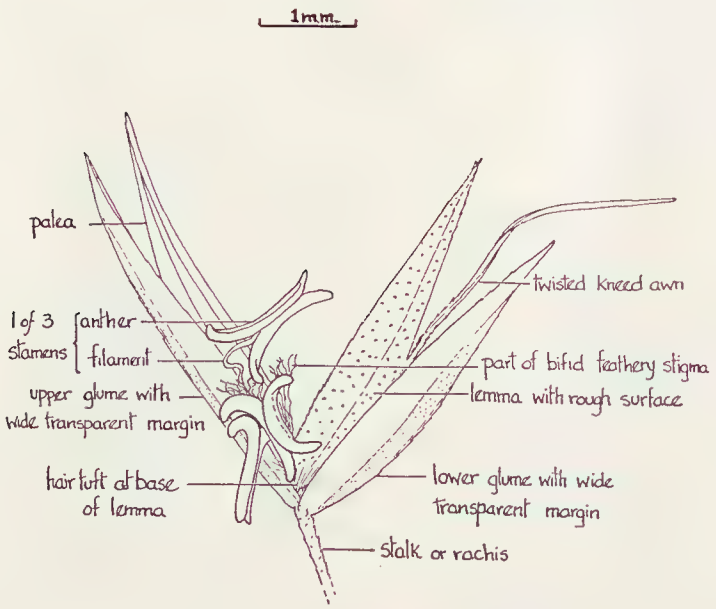


FIG. 2

GRAMINEAE—KEY

The species within each genus (where more than 1) may be keyed out starting from the couplet number as follows:—

Agropyron	96	*Danthonia*	172	*Lolium*	92	*Setaria*	80
Agrostis ..	101	*Deyeuxia*	112	*Microlaena*	139	*Sporobolus*	133
Aira	146	*Dichelachne*	100	*Paspalum* spp. key out at 9 and 17		*Stipa*	126
Alopecurus	85	*Eragrostis*	148			*Tetrarrhena*	137
Amphibromus ..	192	*Festuca*	168			*Vulpia*	158
Avena	142	*Glyceria*	160	*Pennisetum*	81	*Zoisia*	79
Briza	157	*Hierochloë*	140	*Phalaris*	134		
Bromus	161	*Hordeum*	88	*Poa*	149		
Cynosurus	87	*Koeleria*	141	*Polypogon*	83		

GRAMINEAE—KEY TO THE SPECIES IN TASMANIA

1. (*a*) Cultivated cereal up to 15 feet (5 m) high, upright plant with very broad leaves; spikelets of 2 sorts, the male bearing anthers in *large terminal panicles*, and the female spikelets borne in an *axillary cob* about halfway down culm, enclosed in broad leafy bracts; each ovary with a single very long style, the styles from each cob forming a tassel up to 15 cm long .... *Zea mais*

   (*b*) Stout rhizomic perennial creeping widely over coastal sand dunes; inflorescences of 2 sorts, the male composed of sessile spikelets in a loose terminal head, the female inflorescence a *porcupine-like head* about 22 cm wide composed of solitary spikelets each at the base of a long awn-like rachis; plant silvery hairy .... *Spinifex hirsutus*

   (*c*) Coarse rooted, densely tufted, wiry perennial; leaf blades bristle-like, stiff and hard; spikelets 1 flowered, narrow, borne on erect very slender 1-sided spikes 3-8 cm long; lemma short-awned at the tip, ovary with single stigma; moors or heath; rare .... *Nardus stricta*

   (*d*) Habit and inflorescene not as above, ovary always with 2 styles 2

2. (*a*) Broad leaved perennial reeds with culms 5 feet (1.5 m) high or more; panicles *plume-like*, 15-40 cm long, dense, upright, at least the female inflorescences silky hairy 3
   (*b*) Much smaller grasses, or if tall then without a plume-like inflorescence 4
3. (*a*) Flowering stems *leafless*, the leaves crowded at the base of the stems forming a huge tussock, blade margins knife-sharp; male and female inflorescences *on separate plants* (dioecious); *lemmas awned*, hairless in male spikelets .... *Cortaderia selloana*
   (*b*) Flowering stems *leafy*, spikelets hermaphrodite, rachilla segments bearing *long silky hairs*; lemmas smooth *without awns* .... *Phragmites communis*
4. (*a*) Low, spreading grasses in coastal and saline areas; leaves conspicuously 2-ranked (distichous) with inrolled, often *needle-like blades sharply pointed at the tips* 5
   (*b*) Blades not sharply pointed at the tips 6
5. (*a*) Spikelets *2-5 mm long, nearly black* in colour, 1-flowered, in narrow spike-like *racemes, shed with the single glume*; leaf-blades faintly ribbed with smooth veins on upper surface .... *Zoisia* spp. 79
   (*b*) Spikelets *about 2 mm long, dark grey in colour*, 1-flowered in a short spike-like *panicle*; *shed leaving the 2 glumes behind;* leaf-blades coarsely and deeply ribbed on upper surface, the veins with knobby bumps (tuberculate-papillose), and sometimes with scattered hairs on lower surface .... *Sporobolus virginicus*
   (*c*) Spikelets *10-16 mm* long and very flattened, *pale straw coloured*, unisexual (plant dieocious), *many-flowered* in a short *panicle* or *raceme* (± 2.5 cm long); glumes 2, not falling with florets; leaf-blades coarsely and deeply ribbed above but with very tiny bumps on the veins .... *Distichlis distichophylla*
6. (*a*) Spikelet with 1-several *conspicuous bristles* at its base either arranged in an enveloping involucre or singly as modified branches of the panicle 7
   (*b*) Spikelet *without* bristles at its base, but sometimes coarsely hairy on the glumes or stalk 8
7. (*a*) Bristles smooth *long fine hairs*, as long as or slightly longer than the spikelets and mostly at base of the racemes; inflorescence a panicle composed of short, densely packed 1-sided racemes along a main axis; stout annuals up to 1.5 m tall; ligule absent; lemma awned (awn 5-10 mm long) .... *Echinochloa crus-galli*
   (The variety *frumentacea* is a very stout broad-leaved (1-2 cm wide) plant with denser racemes, more turgid spikelets and awnless lemmas.)
   (*b*) Bristles *rough stout* hairs, several to each fertile spikelet, and much longer than spikelet, *persisting* on the axis of the *spike-like* inflorescence after spikelet falls; lemma often transversely wrinkled .... *Setaria* spp. 80
   (*c*) Bristles *rough fine* hairs arranged in an involucre and *falling attached* at base of spikelets .... *Pennisetum* spp. 81
   (Inflorescence of *P. clandestinum* reduced to a cluster of 1-4 subsessile spikelets ± hidden in the uppermost leaf sheath.)
8. (*a*) Inflorescence *like a wind-mill*, with 2 to several spikes or spike-like racemes radiating *from the top of the culm*, the spikelets arranged on *one* side of the branches (secund) 9
   (*b*) Infloresence not like a wind-mill; (if the inflorescence branches secund then the branches *scattered along* the main axis) 10
9. (*a*) Racemes (partial inflorescences) *2*; spikelet flattened *dorsally* (from back to front and lemma has 2 keels), ligule *membranous*; plant with long rhizomes and stolons .... *Paspalum distichum*
   (*b*) Racemes *3* or more; spikelet flattened laterally (from side to side and lemma has 1 keel); ligule a *dense row of short hairs* .... *Cynodon dactylon*
10. (*a*) *Glumes falling with the florets*; spikelet with only 1 grain-producing hermaphrodite floret (a second lower floret may be male or abortive, often reduced to an extra empty lemma) 11
    (*b*) *Glumes remaining on the plant* when the florets have fallen; spikelet with 1 to many grain-producing hermaphrodite florets 21
11. (*a*) Spikelet *dorsally compressed* 12
    (*b*) Spikelet *laterally compressed* 19
12. (*a*) Fertile lemma and palea colourless and transparent (hyaline), *thinner* than the glumes 13
    (*b*) Fertile lemma and palea *firmer* than the glumes 15

13. (*a*) Fertile lemma *awned*; spikelets in aggregates of 7-9, each aggregate subtended by a *sheathing bract* or spathe, and composed of 4-6 male spikelets in a whorl surrounding an inner group of 2 stalked male spikelets and 1 sessile bisexual spikelet; inflorescence an interrupted, leafy, *nodding panicle* .... *Themeda australis*
(*b*) Fertile lemma *awnless*; inflorescence dense and spike-like, spikelets in pairs 14

14. (*a*) Inflorescence a *dense fluffy narrow panicle* with abundant white silky hairs; spikelet pairs unequally stalked; glumes never hooked; plants of sandy or dryish ground .... *Imperata cylindrica*
(*b*) Inflorescence a *rigid rather brittle 4-rowed spike* with spikelet pairs apparently stalkless; spikelets green and hairless; upper glume curved or sharply *hooked at tip*; plants of damp ground near water .... *Hemarthria uncinata*

15. (*a*) Inflorescence a panicle of *slender* 1-sided *subdigitate racemes* (mostly at top of culm but 1 or 2 racemes lower down culm); spikelets hairless or only minutely hairy; fertile lemma with flat, thin transparent margins .... *Digitaria sanguinalis*
(*b*) Panicle not *subdigitate*, a loose panicle or else racemes scattered up culm; fertile lemma with thick inrolled margins 16

16. (*a*) Glumes pointed above and with *a few bristly hairs*; lemma with long awn .... *Echinochloa crus-galli*
(*b*) Glumes and lemmas *awnless* 17

17. (*a*) Lower glume *absent*, or *minute* and rudimentary; spikelets on lower surface of flattened rachis-branch which is long narrow and hairless; racemes 3-5 scattered along main axis .... *Paspalum dilatatum*
(*b*) Lower glume *present*, at least 1/3 length of spikelet 18

18. (*a*) Inflorescence a *nodding rather compact panicle* 10-30 cm long; spikelets 4.5-5 mm long; stout hairy annual plant up to 100 cm high .... *Panicum miliaceum*
(*b*) Inflorescence up to 13 cm long, composed of *several short loose erect racemes* which end in a naked bristle point, spikelets 2.0-3.0 mm long; clumped perennial up to 30 cm high (very occasional introduction) .... *Paspalidium gracile*

19. (*a*) Glumes *awnless* 20
(*b*) Glumes ending in *conspicuous fine awns* .... *Polypogon* spp. 83

20. (*a*) Panicle *pyramidal*, ± *loose*, pinkish; whole plant downy; glumes subequal; *spikelet 2-flowered*, the upper floret male and awned, the lower floret bisexual and awnless .... *Holcus lanatus*
(*b*) Panicle cylindroid and dense, softly hairy; *spikelet 1-flowered*, lemma awned .... *Alopecurus* spp. 85

21. (*a*) Spikelets *sessile* or with minute stalks less than 0.5 mm long, arranged on *one or opposite* sides of the axes 22
(*b*) Spikelets *stalked* on the branches of loose or spike-like *panicles* (rarely racemes) *OR* if quite sessile then arranged *all round* the main axis 32

22. (*a*) Spikelets in one or more rows along *one* side of the axis only 23
(*b*) Spikelets in two rows on *opposite* sides of the axis 25

23. (*a*) Spikelet *1-flowered*, inflorescence a *solitary flat fleshy spike* .... *Stenotaphrum secundatum*
(*b*) Spikelet *with 2 or more florets*, inflorescence a raceme or a spike-like panicle but *not a spike* 24

24. (*a*) Inflorescence a *spike-like panicle*; spikelets with or without awns and of *2 sorts*, fertile ones with 2-4 plump lemmas concealed behind sterile spikelets with several narrow empty bracts; annual or perennial 5-100 cm high .... *Cynosurus* spp. 87
(*b*) Inflorescence a solitary *raceme*; spikelets all alike with more than 3 florets per spikelet; annual 2-30 cm high .... *Catapodium rigidum*

25. (*a*) Spikelets solitary at each joint of spike or raceme 26
(*b*) Spikelets in 3's at each joint of inflorescence, the lateral two spikelets usually reduced or neuter, each spikelet with 1 (or rarely 2) floret; annuals .... *Hordeum* spp. 88

26. (*a*) Spikelets 1-flowered, *sunk in hollows* along the fragile rachis 27
(*b*) Spikelets 2- to many-flowered, *not sunk in hollows* 28

27. (*a*) Spikelet with *single glume* (terminal spikelet may have 2 glumes); spikes straight or slightly curved; anthers 2-3 mm long .... *Monerma cylindrica*
(*b*) Spikelet with *2 glumes*; spikes *very curved* even as much as a half-circle; anthers less than 1 mm long .... *Parapholis incurva*

28. (*a*) Spikelets on *very short stalks* (0.5-2.0 mm), 2-4 in a short spike-like raceme; lemma 7-nerved, long awned .... *Brachypodium distachyum*

(*b*) Spikelets quite *sessile*; if long awned then lemma 5-nerved 29
29. (*a*) Spikelets flattened with keels (edges of spikelet) fitting into depressions along rachis; glume single and abaxial except for topmost spikelet which has 2 glumes .... *Lolium* spp. 92
(*b*) Spikelets flattened with their flat sides pressing against rachis; glumes 2 30
30. (*a*) Perennials often with rhizomes; auricles well developed and often *caliper-like* round culm; spikes flattened; grain remaining enclosed in lemma and palea .... *Agropyron* spp. 96
(*b*) Annuals; spikes ± *cylindrical*; grain falling free from enveloping lemma and palea; cultivated cereals 31
31. (*a*) Spikelet 2-flowered; glumes very *narrow* and strap-shaped; 1-nerved; lemma *narrow*, long awned, stiffly hairy on keel .... *Secale cereale*
(*b*) Spikelet 2-5-flowered; glumes *broad*, 5-7 nerved; lemma *broad*, may be awned, rough along keel .... *Triticum aestivum*
32. (*a*) Spikelets all *sessile* 33
(*b*) Spikelets *stalked* 34
33. (*a*) Spikelets in 3's on opposite sides of flattened rachis; spikelets *1-flowered*; glumes *bristle-like* and long awned .... *Hordeum* spp. 88
(*b*) Spikelets single at each rachis joint; spikelets *2-flowered*; glumes *very narrow* and strap-shaped, not awned .... *Secale cereale*
34. (*a*) Panicle *very softly hairy, globose* to oblong-cylindrical; glumes *feathery-hairy*, each tapering into a fine bristle, lemma with bristle-like apical teeth and a long fine dark dorsal awn 8-18 mm long; annual of sandy places .... *Lagurus ovatus*
(*b*) Panicle not as above; glumes *hairless* or only *shortly hairy* 35
35. (*a*) Spikelets of *one sort* only 36
(*b*) Spikelets of *2 sorts*—fertile ones hidden behind sterile ones .... *Cynosurus* spp. 87
36. (*a*) Spikelet with *1 bisexual fertile floret* (sometimes a male or neuter floret above, sometimes 1-2 male or neuter lemmas below) 37
(*b*) Spikelet with *2-several bisexual fertile florets* 58
37. (*a*) Lemma tip *divided into 2 pairs of teeth* each tooth ending in a fine awn 7-8 mm long; terminal awn between pairs of teeth almost straight 15-25 mm long .... *Pentapogon quadrifidus*
(*b*) Lemma tip *undivided* or slightly bilobed, awnless or with a single awn 38
38. (*a*) Glumes *2* 39
(*b*) Glumes *apparently 4*, the two inner being male or empty lemmas subtending a central bisexual fertile floret and appearing like glumes, the real glumes often minute and inconspicuous 53
39. (*a*) Spikelet with *single bisexual* lemma 40
(*b*) Spikelet with *2 or 3 lemmas* 52
40. (*a*) Lemma bearing an *awn* (may be minute in *Deyeuxia*) 41
(*b*) Lemma *never* awned (glumes may end in awn tip) 49
41. (*a*) Awn *dorsal* (occasionally subterminal when the awn arises from between 2 distinct lobes at tip of lemma); *glumes 1-nerved*; callus of lemma blunt 42
(*b*) Awn *terminal*, very long compared with lemma; glumes *3-7 nerved* at least below 47
42. (*a*) Awn *subterminal*, lemma 2-lobed at tip (minutely so in *Echinopogon*) 43
(*b*) Awn *dorsal* (on back of lemma), lemma smooth-tipped or slightly toothed but not lobed at tip 44
43. (*a*) Panicle soft and *plume-like*; awn very slender, wavy .... *Dichelachne* spp. 100
(*b*) Panicle a very dense rounded spiky head; awn rigid and erect .... *Echinopogon ovatus*
44. (*a*) Glumes *swollen, hardened and shining near base* (like a louse egg); plant 10-50 cm high .... *Gastridium ventricosum*
(*b*) Glumes *not swollen* below 45
45. (*a*) Awn *more than 10 mm* long, wavy; inflorescence a soft plume-like panicle .... *Dichelachne* spp. 100
(*b*) Awn *less than 10 mm* long, *straight* or *kneed* 46
46. (*a*) Panicle *spreading* with very fine branches; lemma membranous and *thinner than the glumes*, usually very *blunt* at tip when flattened out .... *Agrostis* spp. 101
(*b*) Panicle usually *dense and spike-like*; lemma papery or hardened and *thicker than the glumes*, with more or less *pointed* tip .... *Deyeuxia* spp. 112
47. (*a*) Awn persistent, more than 2 cm long 48
(*b*) Awn *deciduous*, less than 1 cm long; lemma *ovoid*, retained round grain and becoming hardened and shiny, callus blunt and without a hair tuft; common perennial with fine cane-like stems up to 4 feet (1.2 m) tall usually found on waste ground *Oryzopsis miliacea*

48. (*a*) Lemma *cigar-shaped,* the *callus sharp-pointed* and with a hairy covering less than half as long as lemma; awn often massive with a twisted column and long fine bristle, kneed at least when dry; inflorescence not deciduous; distributed along dry roadsides and in the lighter parts of dry woodland .... *Stipa* spp. 126

(*b*) Lemma *upside-down-egg-shaped,* broad and flat at top, the callus blunt and with a hair tuft at least half as long as lemma; *inflorescence* deciduous and wind distributed: easily confused with tussock grass in the vegetative state; confined in Tasmania to South Arm and adjacent areas in the S.E. of the State .... *Nassella trichotoma*

49. (*a*) Glumes *awned* and with stout hairs springing out from keel, *less than 5 mm* long; inflorescence a dense cylindrical spike-like panicle 6-15 (rarely up to 30) cm long and 6-10 mm wide. .... *Phleum pratense*

(*b*) Glumes *without awns* 50

50. (*a*) Glumes *more than 10 mm* long; inflorescence a dense spike-like panicle narrowly oblong and tapering upwards, pale coloured, 7-22 cm long, 1-2.5 cm wide; a robust rhizomic grass used for binding coastal sand-dunes .... *Ammophila arenaria*

(*b*) Glumes *less than 5 mm* long 51

51. (*a*) Lemma *hyaline* (colourless and transparent), thinner and shorter than glumes; grain *enclosed* in lemma and palea .... *Agrostis* spp. 102

(*b*) Lemma of similar texture to and as long as or longer than glumes; grain naked and free from lemma and palea .... *Sporobolus* spp. 133

52. (*a*) Glume *winged* down keel; spikelet with 2 (or 1) reduced lemmas not more than half length of upper fertile lemma, awnless .... *Phalaris* spp. 134

(*b*) Glume keeled but *not winged*; spikelet with a lower male floret and an upper bisexual floret, male floret with long twisted kneed awn 10-17 mm long, and bisexual floret with or without a short fine dorsal bristle or awn .... *Arrhenatherum elatius*

(The variety *bulbosum* has bulbous or pear-shaped basal internodes up to 1 cm across, which are very effective means of vegetative propagation.)

53. (*a*) Spikelets *few,* less than 20; outer glumes *very small* and in some cases lower down axis than rest of spikelet 54

(*b*) Spikelets *many* more than 20; outer glumes as long as, or longer than, or nearly equal in length to rest of spikelet 55

54. (*a*) Lemmas *awnless* (may be sharply pointed); stamens 4; inflorescence a short terminal raceme; more or less frail-stemmed scrambling grasses with rough short leaf blades .... *Tetrarrhena* spp. 137

(*b*) Sterile lemmas with unequal slender *scabrid awns*; stamens 4 or 2; inflorescence a loose drooping raceme or a slender sub-racemous panicle; tufty rhizomatous grasses in undisturbed damp situations .... *Microlaena* spp. 139

55. (*a*) Inflorescence a *dense, spike-like erect panicle*; glumes or at least the upper one *longer* than the inner sterile lemmas 56

(*b*) Inflorescence a *loose open* panicle (rarely raceme); glumes *shorter than or not exceeding* the inner sterile lemmas 57

56. (*a*) Glumes *equal,* very flattened, strongly keeled and often winged; non aromatic; sterile lemmas much smaller than fertile lemma *Phalaris* spp. 134

(*b*) Glumes *very unequal,* not winged; aromatic coumarin-scented grass; sterile lemmas hairy and *longer* than fertile lemma, awned, the awn on lower lemma 2-4 mm long and straight, that on 2nd lemma 6-9 mm long and kneed .... *Anthoxanthum odoratum*

57. (*a*) First and second lemmas *enclosing male florets*; palea 1-nerved; aromatic grasses of mountain areas .... *Hierochloë* spp. 140

(*b*) First and second lemmas empty; palea 2-nerved; non-aromatic grass (introduced to South Arm) .... *Ehrharta calycina*

58. (*a*) Spikelets with *2 fertile florets* (rarely 3 in *Avena* and *Trisetum* both of which have kneed dorsal awns attached to upper or central third of lemma) 59

(*b*) Spikelets with *3 or more* fertile florets 63

59. (*a*) Lemma awnless 60

(*b*) Lemma conspicuously *awned* 61

60. (*a*) Ligule *membranous* .... *Koeleria* spp. 141

(*b*) Ligule a *ring of hairs* .... *Sporobolus* spp. 133

61. (*a*) Spikelets *more than 1 cm* long; awns more than 2 cm long; tall annuals with lax panicles .... *Avena* spp. 142

(*b*) Spikelets *less than 7 mm* long 62

62. (*a*) Spikelets *less than 4 mm* long; lemmas sharply *pointed*; small annual grasses up to 40 cm high ..... *Aira* spp. 146
(*b*) Spikelets *4-6 mm* long; lemmas *blunt*; densely tufted perennial to 120 cm high with loose, open panicles ..... *Deschampsia caespitosa*
(*c*) Spikelets *4-6 mm* long; lemmas *acuminate*; alpine perennial with dense spike-like panicles ..... *Trisetum spicatum*

63. (*a*) Lemma with *smooth* tip, not toothed or lobed, either awnless or shortly awned (long awned in *Vulpia* and *Agropyron scabrum*) 64
(*b*) Lemma *3-toothed* at tip or with 2 apical teeth or lobes with an awn arising from between them 74

64. (*a*) Lemma *keeled all down* its back, more or less laterally compressed 65
(*b*) Lemma *rounded* on the back although it may be keeled in the *upper part* only 67
(*c*) Lemma keeled *below* and ± rounded above; spikelets pale yellow, up to 12 mm long in a rigidly erect dense spike-like panicle; leaf-blades very stiff and needle-like, sharply pointed, up to 45 cm long; perennial growing up through beach sands ..... *Festuca littoralis*

65. (*a*) Ligule a *ring of hairs*, spikelets lead-coloured ..... *Eragrostis* spp. 148
(*b*) Ligule membranous 66

66. (*a*) Inflorescence a coarse, knobby, *one-sided panicle* with rough spikelets in several clusters on slender stalks; lemmas minutely or very shortly awned; ligule 2-12 mm long; a dense tufted glabrous (rarely hairy) rather coarse perennial with very broad, sharply folded leaves up to 14 mm wide ..... *Dactylis glomerata*
(*b*) Inflorescence *not one-sided*; lemma *blunt* with colourless transparent margins and tip, *awnless*, often with *long cottony hairs* towards base; ligule less than 5 mm long (except *Poa trivialis* which has a ligule 4-10 mm long) ..... *Poa* spp. 149

67. (*a*) Spikelets erect *or*, if nodding, then awned or with narrow lemmas 68
(*b*) Spikelets *nodding*, plump, in delicate panicles, *awnless*; glumes and lemmas hooded at the apex, very broad; highly decorative annuals ..... *Briza* spp. 157

68. (*a*) Panicle *stiff, upright, one-sided*; spikelet stalks short and thick; lemmas blunt-tipped, awnless; small annual up to 30 cm high ..... *Catapodium rigidum*
(*b*) Panicle *rather lax* with more or less slender spikelet stalks, if one-sided then lemmas long-awned 69

69. (*a*) Glumes *nearly equal*, panicle *regular*; anthers 3 70
(*b*) Glumes *very unequal*, panicle *one-sided*, anther 1, small annuals up to 60 cm high ..... *Vulpia* spp. 158

70. (*a*) Lemma *blunt* tipped, *smooth*, awnless; glumes *blunt* 71
(*b*) Lemma *acute* or acuminate (if not very acute then very scabrid), sometimes awned; glumes *acute* (sharply pointed) 72

71. (*a*) Wet salt marsh plant with *stiff inrolling* leaf-blades; leaf sheath margins *free*; lemma with 5 faint nerves ..... *Puccinellia stricta*
(*b*) Freshwater swamp or mud plants with *lax flat* leaf-blades; leaf sheath margins *fused*; lemma with 5-9 prominent nerves ..... *Glyceria* spp. 160

72. (*a*) Ovary with terminal *hairy appendage* and *lateral* styles; leaf sheaths without auricles; plants annual or biennial (except *Bromus unioloides* a perennial) ..... *Bromus* spp. 161
(*b*) Ovary *without* terminal appendage, styles *terminal*; auricles may be present; plants perennial 73

73. (*a*) Tall coarse forest grass 1.5-3 m high in tall wet sclerophyll forest; lemmas slightly laterally compressed; hilum about 1/3 length of grain ..... *Dryopoa dives*
(*b*) Habit and habitat not as above; lemmas *circular in cross-section*; hilum a fine line as long as the grain ..... *Festuca* spp. 168

74. (*a*) Glumes *longer* than lowest lemma, often as long as whole spikelet; lemma 7-nerved or more 75
(*b*) Glumes *shorter* or no longer than lowest lemma 76

75. (*a*) Lemma *deeply 2-lobed* above, with *kneed awn* arising between lobes, more or less hairy (often densely) on the back ..... *Danthonia* spp. 172
(*b*) Lemma *shortly 3-toothed* at tip, awnless; spikelets plump, 6-12 mm long ..... *Sieglingia decumbens*

76. (*a*) Lemma *minutely 3-lobed* at tip, *awnless* ..... *Glyceria* spp. 160
(*b*) Lemma torn or *denticulate* at tip with at least 4 minute lobes or teeth, with *dorsal kneed awn* more than 1 cm long; spikelets with up to 7 florets in loose panicles ..... *Amphibromus* spp. 192

(*c*) Lemma *not denticulate* (may be slightly bifid at tip); awns less than 1 cm, or if more than 1 cm then straight or curved and *not kneed* 77

77. (*a*) Lemma *5-nerved* or more, with subterminal awn 2 mm or more long 78
(*b*) Lemma *3-nerved*, if awned then awn less than 2 mm long ..... *Koeleria* spp. 141

78. (*a*) Whole spikelets *less than 5-flowered*; rachilla joints with *long, soft hairs*; awns *bent* and up to 6 mm long ..... *Trisetum spicatum*
(*b*) Whole spikelets *more than 5-flowered* (rarely less); rachilla *without* long soft hairs; awns straight or if curved then more than 6 mm long ..... *Bromus* spp. 161

79. (*a*) Stems very short *usually less than 2.5 cm* high and not often exceeding 5 cm; spikelet 2-3 mm long; leaf-blades with *short* sharp point; anthers about 1 mm long; rare introduction in lawn grass in Hobart and St Helens areas ..... *Zoisia matrella*
(*b*) Stems usually more than 5 cm long; spikelet 3.5-5 mm long; leaf-blades with a *long* sharp point, anthers 1.5-2 mm long; Bass Strait Islands ..... *Zoisia macrantha*

80. (*a*) Panicle-bristles with barbs pointing forwards towards tips ..... *Setaria viridis*
(*b*) Panicle-bristles with *reflexed* barbs (pointing away from tips) ..... *Setaria verticillata*

81. (*a*) Inflorescences *almost completely hidden* within uppermost leaf-sheaths with only the stigmas projecting, reduced to 2-4 spikelets; a coarse matted perennial with *long creeping* rhizomes, stout profusely branched stolons and conspicuously 2-ranked leaves; leaf sheaths smooth or hairy; ligules densely ciliate ..... *Pennisetum clandestinum*
(*b*) Inflorescence an obvious panicle 82

82. (*a*) Panicle *narrow, cylindrical*; involucre bristles *about as long* as spikelet; styles more or less free ..... *Pennisetum macrourum*
(*b*) Panicle *ovoid* (egg-shaped); involucre bristles *much longer* than spikelet; styles joined almost to tips; Bass Strait Islands ..... *Pennisetum villosum*

83. (*a*) Glume awn *up to 2 mm* long; lemma awn up to 3 mm long; anthers devoid of pollen (male-sterile, intergeneric hybrid); perennial occurring in muddy ditches ..... *Polypogon littoralis*
(*b*) Glume awn *6 mm* or more long; annual 84

84. (*a*) Glumes *slightly* notched, *shortly hairy*, the hairs lying close to the glume surface; glume awn 4-7 mm long, yellowish-green, borne almost at the tip of the glume ..... *Polypogon monspeliensis*
(*b*) Glumes *deeply divided* to about the middle into 2 lobes, covered in long hairs which are stiff and spreading at the base, glume awn about 4 mm long, pink or purplish, borne at the base of the glume notch; coastal grass ..... *Polypogon maritimus*

85. (*a*) Keels of glumes *fringed with long hairs*; glume margins united *only near base* 86
(*b*) Keels of glumes *minutely hairy*; glume margins united up to half their length; spikelets 4.5-7 mm long; annual of arable and wasteland ..... *Alopecurus myosuroides*

86. (*a*) Culms *spreading* with short stolons rooting at the nodes; panicles *3-7 mm wide*; spikelets 2.5-3.5 mm long; anthers 1.5-2 mm long; occurring in wet open places ..... *Alopecurus geniculatus*
(*b*) Culms *erect* 30-120 cm high, panicles 5-10 mm wide; spikelets 4-6 mm long; anthers 2-3.5 mm long; hedge row remnant of old pastures ..... *Alopecurus pratensis*

87. (*a*) Compactly tufted rhizomatous *perennial* with unbranched culms; panicles *narrowly oblong*, 4-10 mm wide; fertile spikelets 3-6 mm long; lemma awn up to 1 mm long ..... *Cynosurus cristatus*
(*b*) *Annual* often with branched culms; panicle *ovate to oblong*, very bristly, 10-20 mm wide; fertile spikelets 8-14 mm long; lemma awn 6-16 mm long ..... *Cynosurus echinatus*

88. (*a*) Spike-axis *tough*, continuous and persistent; cultivated barleys 89
(*b*) Spike-axis *fragile*, readily breaking up between the spikelet groups; wild grasses 90

89. (*a*) Spikes with 6 or apparently 4 rows of fertile spikelets; each spikelet of triplet fertile and sessile ..... *Hordeum vulgare*
(*b*) Spikes with 2 rows of fertile spikelets; spikelet triplet with two lateral stalked reduced spikelets and a median sessile fertile spikelet ..... *Hordeum distichon*

90. (*a*) Glumes hairless 91

(*b*) Glumes of at least the central spikelet *expanded and hairy*, all 3 lemma awns of spikelet triplet *much longer* (up to 5 cm) than the 6 glume awns; lateral spikelet lemmas (even without the awns) *longer and wider* than central lemma .... *Hordeum leporinum*
(The closely related Eurasian *H. murinum* L. (Wall Barley) differs from *H. leporinum* in having lateral spikelets *no longer or wider* than the central one.)

91. (*a*) Both glumes of lateral spikelets *bristle-like*, not expanded .... *Hordeum hystrix*
(*b*) Glumes of lateral spikelets *dissimilar*, the one opposite the lemma bristle-like, the one opposite the palea *broadly-winged* on one side (obscured in dry specimens) .... *Hordeum marinum*

92. (*a*) Glume as *long as* or *exceeding* the uppermost lemma 93
(*b*) Glume much *shorter* than the spikelet 95

93. (*a*) Lemmas *eggshaped to elliptic, swollen* about the grain .... *Lolium temulentum*
(*b*) Lemmas more or less *lanceolate, never* swollen 94

94. (*a*) Glume *more than 1 cm* long *not quite as long* as spikelet; lemmas awnless; spikelet about 2 cm long and rigidly erect at maturity *Lolium rigidum*
(*b*) Glume *less than 1 cm* long (more or less 7 mm), *longer than* the spikelet; uppermost lemma shortly awned; spikelet about 1.4 cm long .... *Lolium loliaceum*

95. (*a*) Lemmas *awnless; perennial* with young leaf blades of vegetative shoots *folded* about the midrib .... *Lolium perenne*
(*b*) Lemmas with fine straight *terminal awns* up to 1 cm long; annual or biennial with leaf blades *rolled* in the young shoots .... *Lolium multiflorum*
(H 1 Rye-grass is a selection of Short Rotation Rye-grass = *Lolium perenne* x *Lolium multiflorum*. Tasmanian Ryegrass No. 1 is a selection of *Lolium perenne*.)

96. (*a*) Inflorescence *drooping and slender*; lemma awns *2.5-5 cm* long and *curving outwards* in mature inflorescence; 2-12 spikelets about 5 cm long (including awns) usually distant (standing apart) on the rachis; hairless to very hairy perennial up to 1 m high .... *Agropyron scabrum*
(*b*) Inflorescence *erect* 97

97. (*a*) Inflorescence more or less *hairy*; plants tufted or with very short rhizomes 98
(*b*) Inflorescence *hairless*; plants with *long slender creeping rhizomes* 99

98. (*a*) Stems 30-60 cm high; leaf-blades *lax*; inflorescence up to 13 cm long with well spaced spikelets which become *reflexed* from main axis .... *Agropyron pectinatum*
(*b*) Stems less than 30 cm high; leaf blades *rigid* not drooping; inflorescence 2.5-5 cm long, short and stout with crowded *erect* spikelets; high alpine .... *Agropyron velutinum*

99. (*a*) Auricles *present*, caliper-like at base of smooth leaf blades (veins not prominent); upper surface of blade *hairless* or with *short scattered hairs*; spike *slender*, dull green, with a tough persistent rachis; glumes blunt or sharply pointed, *less than 2 mm* wide *Agropyron repens*
(*b*) Auricles *absent*; leaf blades prominently veined and *densely and minutely hairy* on upper surface along the veins; spike *stout*, bluish-grey, with a fragile rachis readily breaking just above each spikelet; glumes blunt tipped, *2-4 mm* wide; sand-dune plant tolerating salt water .... *Agropyron junceum*

100. The genus *Dichelachne* requires revision but one species is more or less distinct:—
(*a*) Panicle very *dense and spike-like*, pale coloured; glumes *equal* with long drawn out tips; lemma awns 1.5-5 cm long and distinctly lateral, flexuous without distinct column and bristle .... *Dichelachne crinita*
(*b*) Panicle *loose* although somewhat contracted; glumes *unequal*; awns with distinct column and bristle—a group of species including:—
Dichelachne sciurea—robust plant with fairly dense inflorescences
Dichelachne rara—more slender plant with more spreading delicate inflorescences and fewer spikelets
Dichelachne spp.—2 or 3 as yet undifferentiated but superficially similar to previous 2 spp.
Previous specimens in this group have usually been placed with *D. sciurea*.

101. (*a*) Lemma *awnless*, or if present then minute and delicate 102
(*b*) Lemma *with awn*, awn, 1½-twice length of glumes 109

102. The key to species of *Agrostis* adapted from that of J. C. Willis (1962) and J. W. Vickery (1941):—
(*a*) Panicle *diffuse* with long verticillate spreading branches, spikelets far apart on hair-like stalks; lemma and palea *more or less equal* in length; a weak grass very rough to the touch and growing in shady places .... *Agrostis rudis*
(*Agrostis aequata* Nees differs only in the smaller less acute or less scabrid glumes and is treated by J. H. Willis as a variant of *A. rudis*.)
(*b*) Panicle *erect*, not widely spreading, or if somewhat spreading then palea absent 103

103. (*a*) *Perennials* with culms 30 cm high or more, mostly with rhizomes and/or stolons; leaf blades *flat* never filiform; palea present or absent 104
(*b*) *Annuals* (or at most biennials) less than 30 cm high with mostly *inrolled or filiform* leaf blades; palea absent (mostly alpine tufted grasses) 107

104. (*a*) Palea *present*, shorter than lemma; panicle often open; plants with long thin rhizomes and/or stolons 105
(*b*) Palea *absent*; panicle loose and wide spreading; sometimes with a short horizontal rhizome; occurring in damp shady places .... *Agrostis hiemalis*

105. (*a*) Plant *without rhizomes*, spreading by stolons only; panicles *contracted* and *usually dense after flowering*; leaf usually bluish-green with a ligule *1-6 mm* long; flowering mid-January to March .... *Agrostis stolonifera*
(*b*) Plant with rhizomes; panicles remaining open, leaf bright or dull green; flowering November to March 106

106. (*a*) Panicle often with olive brown colour; leaf bright green; ligule *0.5-2 mm* long and *shorter than broad;* slender grass 10-70 cm high, flowering late November to March .... *Agrostis tenuis*
(*b*) Panicle often purplish; leaf dull green; ligule *1.5-6 mm* long and at least *as long as broad*, robust grass 30-120 cm high, flowering mid-December to March .... *Agrostis gigantea*

107. (*a*) Inflorescence a *spreading* panicle 108
(*b*) Inflorescence a *contracted* panicle with upright branches; blades almost flat or slightly rolled; ligule pointed above, 2-3 mm long *Agrostis muelleriana*

108. (*a*) Pyramid-shaped panicle carried *well beyond upper leaf sheath*, its branches short (1-3.5 mm towards base); anthers 0.3-0.5 mm; leaf blades thread-like bristles up to 11 mm long and 0.25-1 mm wide .... *Agrostis parviflora*
(*b*) Panicle lax, its lower branches *remaining enclosed in upper sheath* and almost erect; panicle branches *long and hair-like* .... *Agrostis australiensis*

109. (*a*) Lemma *with long hairs* on back 110
(*b*) Lemma *quite smooth* on back or only minutely rough 111

110. (*a*) Panicle *widely spreading* with *drooping branches*; spikelets 2-4 mm long, usually pale green; anthers less than 0.6 mm long .... *Agrostis avenacea*
(*b*) Panicle *not* widely spreading, its branches never drooping; spikelets 3.5-6 mm long, purplish with age; anthers 0.6-1.2 mm long .... *Agrostis aemula*

111. (*a*) Palea *present*, 2/3 length of lemma; leaf blades *flat*, 2-8 mm wide; *ligule 4-8 mm* long; rachilla *extending beyond floret* as a long-haired bristle 1-2 mm long; callus densely hairy; grass of sandy shore lines .... *Agrostis billardieri*
(The vars. *filifolia* and *robusta* are more typically inland grasses with narrower leaves 1-1.5 mm wide). The var. *filifolia* has a more slender, taller habit than the type, while var. *robusta* differs in its tall erect rigid habit up to 60 cm high.)
(*b*) Palea *absent*; leaf blade *thread-like*; ligule *2-3 mm* long; rachilla not extending beyond floret; callus without hairs; grass of damp, high situations .... *Agrostis venusta*

112. The key to species of *Deyeuxia* is adapted from that of J. W. Vickery (1940) and of J. C. Willis (1962)—
(*a*) Upper glume distinctly *shorter* than lemma 113
(*b*) Upper glume *longer* than lemma (only slightly longer in some cases) 114

113. (*a*) Panicle *2-9 cm long* with short, stiff branches; spikelets about 1.5 mm long; lemma *smooth*, about twice as long as glumes, bearing an awn 0.2-0.7 mm long; rachilla ending in a smooth or slightly hairy bristle ..... *Deyeuxia gunniana*
(*b*) Panicle *12-20 cm long*, loose and spreading with almost nodding branches; spikelets 1.5-2.5 mm long; lemma *distinctly rough, less than twice length* of glumes, bearing an awn 0.2-0.4 mm long; rachilla ending in a stiffly hairy bristle about 1 mm long, the hairs 0.2-1.2 mm long ..... *Deyeuxia parviseta*

114. (*a*) Awn *much longer* than lemma 115
(*b*) Awn *not longer* or only just longer than lemma, sometimes *minute* and shed early 122

115. (*a*) Awn arising near base of lemma *in the lower 1/3* of its length; inflorescence a dense spike-like panicle 116
(*b*) Awn arising in *middle 1/3* of lemma 118
(*c*) *Awn arising in upper 1/3* of lemma, 4-6 mm long, rather stiff, *reflexed*; panicle rather loose, sometimes spreading, 8-17 cm x 0.8-2 cm; alpine or subalpine ..... *Deyeuxia brachyathera*

116. (*a*) Lower glume *shorter* than the upper; leaf blade long and pointed, needle-like ..... *Deyeuxia monticola*
(*b*) Lower glume *longer* than the upper; leaf blade never needle-like 117

117. (*a*) Spikelets about *8 mm* long; lemma about *1/2 length of lower glume*, 4-5 mm long ..... *Deyeuxia lawrencei*
(*b*) Spikelets *3-6 mm* long; lemma at least 2/3 length of lower glume and *distinctly 4-toothed at the apex*, grass with very variable habit from slender to robust ..... *Deyeuxia quadriseta*

118. (*a*) Panicle loose, *spreading* at least when anthers mature; spikelets 4.5-5 mm long, borne *towards the ends* of the panicle branches; upper glume slightly *longer* than lower; awn 3-4 mm long; anthers about 2 mm long, maroon coloured with dark orange pollen; growing in sub-alpine woodland ..... *Deyeuxia accedens*
(*b*) Panicle *dense and spike-like*, or if somewhat loose then the spikelets on the lateral branches borne almost from the main axis up 119

119. (*a*) Spikelets usually *under* 5 mm long 120
(*b*) Spikelets usually *over* 5 mm long 121

120. (*a*) Panicle *very short*, less than 4 cm long, usually 1-2 cm long, *dense*; stems stiff and upright from the base; rachilla not usually extending beyond lemma ..... *Deyeuxia minor*
(*b*) Panicle *5-15 cm* long, *loose* although contracted; stems weak, curving from the base upwards; rachilla ending in an almost hairless bristle about 1 mm long ..... *Deyeuxia rodwayi*

121. (*a*) Rachilla ending in a *very short fine hairless bristle* 0.5 mm long; leaves more or less thick and rigid; alpine grass ..... *Deyeuxia carinata*
(*b*) Rachilla ending in a *long-haired bristle* up to 2 mm long; leaves rather thin and pointed; lowland or higher ground ..... *Deyeuxia densa*

122. (*a*) Awn arising from *middle 1/3* of lemma 123
(*b*) Awn arising from *within upper 1/3* of lemma 124

123. (*a*) Rachilla ending in an *almost hairless bristle* about 1 mm long; awn *curved*; plant slender, *stems curving* from the base; mountain-forest grass ..... *Deyeuxia rodwayi*
(*b*) Rachilla ending in a bristle *0.8 mm long with a tuft of short hairs* at the tip; awn *straight*; plant robust with *erect* stems ..... *Deyeuxia benthamiana*

124. (*a*) Lemma *surface smooth*; spikelet about 2.5 mm long; callus densely hairy; rachilla bristle hairy (hairs up to 1.4 mm long) ..... *Deyeuxia parviseta* var. *Boormani*
(*b*) Lemma *surface rough* 125

125. (*a*) Rachilla bristle *hairy*; spikelets 3-3.2 mm long; ligule *pubescent*, 2-3 mm long; anthers about 1.5 mm long ..... *Deyeuxia scaberula*
(*b*) Rachilla bristle *without hairs*; spikelets about 2.5 mm long, ligule *membranous* 2-3 mm long; anthers less than 0.5 mm ..... *Deyeuxia contracta*

126. (*a*) Leaf blades *needle-shaped, sharply pointed* at the tip, about 60 cm long, hairless; lemma 10-15 mm long, covered with whitish hairs about 2mm long; glumes 17-18 mm long; tussock-forming perennial growing in shingle at highwater mark ..... *Stipa teretifolia*
(*b*) Leaf blades *not needle shaped* or sharply pointed at tip 127

127. (*a*) Young leaf blade rolled, ☞ *in section*, with *one margin* inside 128
(*b*) Young leaf blade rolled, ☞ *in section* with *two margins* rolled in 129

128. (*a*) Lemma awn *slender* (0.3 mm diameter), and shortly hairy (hairs less than 0.9 mm long), column 1.4-3 cm long, bristle 3-7 cm; lemma densely silky hairy with a *crowning tuft of hairs 2-5 mm* long at base of awn .... *Stipa stuposa*
(*b*) Lemma awn *stouter* (0.5 mm diameter), column more or less 3.5 cm long and shortly hairy (hairs up to 1.5 mm long), bristle about 4.5 cm long; lemma hairs *not* forming a crowning tuft .... *Stipa semibarbata*

129. (*a*) Awn gently *curving*, the column *grading imperceptibly* into the bristle, *plumose* with long silky hairs 2 mm long *extending about 2/3 way along the bristle*; upper surface of blade *densely* hairy with a felt of white hairs 0.2 mm long .... *Stipa mollis*
(*b*) Awn *kneed* with long, straight, more or less hairless, twisted column and once or twice bent bristle 130

130. (*a*) *Bristle* curved like a sickle when dry .... *Stipa variabilis*
(*b*) Bristle *straight* 131

131. (*a*) Lemma hairs *deep copper coloured*; lemma *spindle-shaped* with 2 minute lobes (0.2 mm long) at base of awn; mostly confined to strictly low-lying coastal areas .... *Stipa compacta*
(*b*) Lemma hairs yellowish, creamy or white, *without lobes*, lemma only slightly wider at the middle than at the ends; roadsides and/or open dry woodland 132

132. (*a*) Column of awn *stout* (0.5 mm thick); ligule a *fingernail-shaped membrane* 0.8 mm or more long; panicle usually 1-sided, well above the uppermost leaf sheath .... *Stipa pubescens*
(*b*) Column of awn *more slender* (0.25 mm thick); ligule a *minute truncate membrane* about 0.5 mm long; panicle usually drooping pyramid-shaped (in still air), basal side branches enclosed in uppermost sheath at start of flowering .... *Stipa nervosa*

133. (*a*) Coarse *densely tufted* grass; leaf blades *more than 8 cm long*, very tough but drooping; growing in sandy coastal areas .... *Sporobolus capensis*
(*b*) Low creeping grass, leaf blades markedly 2-ranked and *less than 5 cm long*; growing in saline mud of inland and coastal flats .... *Sporobolus virginicus*

134. (*a*) *Perennial* with rhizomes or bulbous basal stem swellings 135
(*b*) Tufted *annual* 136

135. (*a*) Glumes almost if not quite wingless; panicle lanceolate to oblong, lobed, 5-25 cm long, 1-4 cm wide; sterile lemmas 2, *more or less equal, silky-hairy*, up to 1/2 length of fertile lemma; marsh plant with stout reed-like culms growing by or in ponds and slow moving water, and spreading by creeping rhizomes .... *Phalaris arundinacea*
(*b*) Glumes with *broadly winged keels*; panicle *long-cylindrical* 8-15 cm long, 1-2 cm wide; sterile lemmas 2, *unequal*, the longer 1/3 length of fertile lemma, the shorter 1/3 length of the longer; anthers deep orange-yellow, 3 mm long; plant with short rhizomes and *bulb-like swellings* at the base of mature culms .... *Phalaris tuberosa*

136. (*a*) Panicle *shortly cylindrical to oblong*, 1-5.5 cm long, 0.8-1.6 cm wide; *sterile lemma 1*; anthers lemon-yellow, 1 mm long; annual (often confused with *P. tuberosa*, but may be most easily distinguished on the anther character and the number of sterile lemmas) .... *Phalaris minor*
(*b*) Panicle *ovate*, 1.5-6 cm long, 1.2-2.2 cm wide; *sterile lemmas 2*, 3-4.5 mm long .... *Phalaris canariensis*
(*Phalaris coerulescens* Desf. is a perennial species similar to *P. tuberosa*, and may be distinguished by the *purple colouration* on the spikelets and the *absence of both sterile florets*. Strain trials have been carried out at Cressy Agricultural Research farm.)

137. (*a*) True glumes *more or less 1 mm* long 138
(*b*) True glumes *2-3 mm* long; *upper sterile lemma 4 mm* long; scrambling *wiry* rough-stemmed grass with flat, rough leaves .... *Tetrarrhena juncea*

138. (*a*) Sterile lemmas *acuminate*, the *upper 7 mm* long (including minute awn 0.5 mm long); weak slender grass .... *Tetrarrhena acuminata*
(*b*) Sterile lemmas ± *mucronate*, the *upper 4 mm* long (including mucro 0.1 mm long if present); weak mat-forming grass .... *Tetrarrhena distichophylla*

(An apparently undescribed, small tufted alpine grass intermediate in character between *T. acuminata* and *T. distichophylla* occurs in short turf round small lakes in the vicinity of Hartz Mountain.)

139. (*a*) A tuft of hairs present on a naked length of rachilla between the true glumes and the lower sterile lemma; inflorescence a *nodding* raceme or slender panicle ..... *Microlaena stipoides*
(*b*) True glumes *close to and overlapping* the base of the sterile lemmas; spikelets about 10 mm long in ± erect narrow panicles 5-10 cm long ..... *Microlaena tasmanica*
(*c*) As for (*b*) but spikelets about 5 mm long; panicles 3-5 cm long ..... *Microlaena tasmanica* var. *sub-alpina*

140. (*a*) True (outer) glumes *5-7 mm long, as long as* the spikelet; lemma awned; culms about 90 cm tall ..... *Hierochloë redolens*
(*b*) True glumes *4 mm long,* nearly as long as the spikelet; lemmae awned; culms about 30 cm tall ..... *Hierochloë fraseri*
(*c*) True glumes *2.5 mm* long, *much shorter* than the spikelet; lemmae *without* awns; culms 60-90 cm tall ..... *Hierochloë rariflora*

141. (*a*) Small ± ascending *annual,* about 25 cm high ..... *Koeleria phleoides*
(*b*) Compactly tufted *perennial* 10-60 cm high, sometimes with slender wiry rhizomes ..... *Koeleria cristata*

142. (*a*) Lemma *practically hairless,* spikelets *not shattering* at maturity 143
(*b*) Lemma *copiously hairy,* spikelets *breaking up at* maturity above the glumes and/or between the lemmas 144

143. (*a*) Apex of lemma with *2 fine bristles* 3-9 mm long; dorsal awn 20-35 mm long ..... *Avena strigosa*
(*b*) Apex of lemma *slightly 2-toothed,* without bristles; awned or awnless, awn when present almost straight, only slightly twisted ..... *Avena sativa*

144. (*a*) Lemma apex with *2 fine bristles* 3-7 mm long ..... *Avena alba*
(*b*) Lemma apex *shortly toothed* 145

145. (*a*) Rounded scar *at base of each lemma,* 2-3 flowered, all lemmas with kneed awn, and densely bearded round the scar; spikelets 18-25 (rarely 30) mm long ..... *Avena fatua*
(*b*) Scar at base of *lowest lemma only,* 2-3 flowered, 3rd lemma awnless; spikelets 23-32 mm long ..... *Avena ludoviciana*
(Some confusion exists between this species (Winter Wild Oat) and the larger-spikeleted *A. sterilis* L. (Animated Oats) which has been found growing on the University of Tasmania campus!)

146. (*a*) Panicle dense, *spike-like,* lemmas *almost equalling* the glumes, *both awned* with the awn of the lower lemma shorter than that of the upper ..... *Aira praecox*
(*b*) Panicle *open,* lemmas shorter than the glumes 147

147. (*a*) Lower floret with *awn as long as that of upper floret* ..... *Aira caryophyllea*
(*b*) Lower floret *awnless* or nearly so ..... *Aira elegans*

148. (*a*) *Perennial* with fine drooping leaves; spikelets *up to 15-flowered,* about 2 mm wide; lemma pointed, 2 mm long ..... *Eragrostis brownii*
(*b*) *Smelly annual*; spikelets up to 30-flowered, about 3 mm wide; lemma blunt-tipped, about 2.5 mm long ..... *Eragrostis cilianensis*

149. (*a*) *Annual* or short lived perennial without stolons, rhizomes or bulbous basal swellings; inflorescence branches *smooth*; ligules 2-5 mm long; spikelets 3-10 mm long ..... *Poa annua*
(*b*) Perennials, tussocky or with stolons, rhizomes or bulbous swellings 150

150. (*a*) *Tufted bulbous-based* turf species 5-40 cm high; spikelets *variegated* with green, gold, purple and white ..... *Poa bulbosa*
(*b*) Plant *not* bulbous based 151

151. (*a*) Plant narrow leaved and tussocky, without stolons or rhizomes 152
(*b*) Plant spreading by rhizomes or stolons 153

152. (*a*) Coastal grass with involute leaves *30-90 cm* long and inflorescences *not carried above the leaves*; panicle more or less *dense,* 10-30 cm long, with *branches in whorls of 3-5* ..... *Poa poiformis*
(*b*) Plants not confined to coastal areas; inflorescences *carried well clear* of the leaves; panicle becoming *loose* with most branches *paired*; the common large bulky tussock of lowlands and uplands ..... *Poa labillardieri*
(*P. labillardieri* has been lumped with at least 3 species including a commonly viviparous small alpine under the epithet *Poa australis* agg.; the whole tussock grass taxonomy awaits critical elucidation.)

153. (*a*) *Weak slender* grass of damp shaded places, with variably stoloniferous culms; blades *less than 1 mm* wide, smooth, inrolled almost hairlike; spikelets 2-4 mm long with 2-4 (rarely 5) florets ..... *Poa tenera*
(*b*) Plants not so, with ± flat leaf blades 154
154. (*a*) Plants with *long or short rhizomes*; ligules not more than 3 mm long 155
(*b*) Plants 20-100 cm high with *creeping leafy stolons*; ligules pointed, *4-10 mm* long; blades abruptly and sharply pointed, 3-20 cm long, 1.5-6 mm wide, an occasional relic of old pastures ..... *Poa trivialis*
155. (*a*) *Alpine* plant 30-45 cm high with broad *plump spikelets*, the glumes 4-5 mm long; leaf blades almost as long as the culm, ligule 2-3 mm long ..... *Poa saxicola*
(*b*) *Lowland* plant with *flattened* spikelets, spreading by long creeping rhizomes 156
156. (*a*) Leaf blades up to *30 cm* long, not rigid; culms *circular* in section; panicle branches *rough with minute hooks*; very variable with creeping *slender* rhizomes ..... *Poa pratensis*
(*b*) Leaf blades *2-12 cm* long, rigid; culms *flattened* in section; stiff perennial spreading by *wiry* rhizomes ..... *Poa compressa*
157. (*a*) Spikelets 7-20 flowered, *14-25 mm long* and *8-15 mm wide, few* in number; annual ..... *Briza maxima*
(*b*) Spikelets 4-12 flowered, *3-7 mm long and wide, many* per inflorescence ..... *Briza minor*
(*Briza media* is a European *rhizomatous perennial* species not so far recorded for Tasmania.)
158. (*a*) Lower glume *0.5-2 mm* long, upper glume 3-7 mm long; panicle base ± enclosed in upper leaf sheath 159
(*b*) Lower glume *2-5 mm* long, *at least half the length of the upper glume*; panicle carried well beyond uppermost leaf sheath ..... *Vulpia bromoides*
159. (*a*) *Apical* third of the lemma margin (at least the uppermost) with *parallel hairs* ..... *Vulpia megalura*
(*b*) Lemma margins *hairless* ..... *Vulpia myuros*
160. (*a*) Plants reed-like with *stout robust culms* 1-2 m high; leaf-blades broad (7-20 mm) *spikelets very numerous* (more than 100 per panicle), oblong, 5-10 mm long with 4-8 florets; lemmas *very blunt, 3-4 mm* long ..... *Glyceria maxima*
(*b*) Plants with *slender rather weak culms* 1/2-1 m high; leaf blades narrow (3-4 mm) and pointed; spikelets *few*, linear, *10-25 mm* long with 6-20 florets; lemmas *pointed* 6-10 mm long ..... *Glyceria australis*
(*c*) Plants usually loosely tufted with *erect, ascending, or prostrate* culms 10-45 cm high; leaf blades 1.5-8 mm wide; spikelets few, *13-25 mm* long with 8-15 florets; *lemmas 3-toothed or 3-lobed* at tip ..... *Glyceria declinata*
161. (*a*) Lower glume with *1 or 3 nerves*, annuals with ultimately *divergent* florets 162
(*b*) Lower glume with *5 or 7 nerves*, annuals or perennials with *contracted* florets 164
162. (*a*) Panicle *very loose* or spreading, branches (lower ones at least) longer than 2 cm 163
(*b*) Panicle *dense* and usually purple tinted, brush-like, the branches rarely longer than 2 cm; spikelets including awns 3.5-6 cm ..... *Bromus madritensis*
163. (*a*) Spikelets including awns *7-9 cm* long; awns 3.5-6.0 cm long ..... *Bromus diandrus*
(*b*) Spikelets including awns 2.5-6 cm long; awns 1-3 cm long ..... *Bromus sterilis*
164. (*a*) Panicle *open* and spreading; lemma sharply keeled and *strongly flattened*; awn *much shorter* than lemma; annual to perennial 165
(*b*) Panicle *dense*; lemma *rounded on back*; awn *as long as or longer* than lemma; downy annual 166
165. (*a*) Spikelets *covered in fine appressed hairs*, up to *5 mm wide*; awns 5-7 mm long; panicle *erect* ..... *Bromus cebadilla*
(*b*) Spikelets *hairless* or minutely rough, *5-10 mm wide*; awns 4 mm or less; panicle *drooping* at maturity ..... *Bromus unioloides*
166. (*a*) Spikelet *more than 2 cm* long; glumes acuminate; awns bent, more than 1 cm long, *spreading outwards* and curling round spikelets in old age, inserted 4-5 mm below notched lemma tip ..... *Bromus macrostachys*
(*b*) Spikelets *less than 2 cm* long; glumes broadly acute to blunt; awns *erect*, less than 1 cm long 167
167. (*a*) Lemmas *8-11 mm* long, mostly *hairy* ..... *Bromus mollis*
(*b*) Lemmas *6.5-8 mm* long, *hairless* ..... *Bromus thominii*

168. (*a*) *Flat-leaved,* robust perennials with blades 3-20 mm wide 169
(*b*) *Rolled-leaved,* tufted perennials with blades about 1 mm wide 171

169. (*a*) Callus bearing *a tuft of hairs*; leaf blades *finely* ribbed (6-7 ribs per mm), more or less scabrid, seldom more than 15 cm long; spikelets 9-18 mm long; grass growing in open damp woodland with *very loose somewhat nodding panicle* about 30 cm long carried high above the foliage .... *Festuca hookeriana*
(*b*) Callus *hairless,* panicle *erect or slightly contracted* 170

170. (*a*) Leaf blades *almost smooth,* usually *more than 15 cm* long; grain *tightly enclosed* by the hardened lemma and palea .... *Festuca arundinacea*
(*b*) Leaf blades *roughly hairy* on top surface, *up to 8 cm* long; grain *free* from lemma and palea .... *Festuca plebeia*

171. (*a*) Leaf blades *rough* to touch; panicle bluish-green; lemma 6-8 mm long; anthers *4-5 mm*; sub-alpine and lower-growing grass up to 90 cm high .... *Festuca asperula*
(*b*) Leaf blades *bristle-like and smooth*; panicle green-purplish; lemma 4-6 mm; anthers *2-3 mm*; lawn grass rarely over 60 cm high, *with creeping rhizomes* .... *Festuca rubra*
(The var. *commutata* Gaud. (syn. var. *fallax* Hackel) is Chewing's Fescue which differs from the typical *F. rubra* in the absence of creeping rhizomes.)

172. The key to the species of *Danthonia* is adapted from that of J. W. Vickery (1965). N.B.: The body of the lemma is measured to include the callus and up to the bottom of the sinus between the 2 lemma lobes:—
(*a*) Lemma body with *upper row of hairs* plus *many hairs scattered over the back* 173
(*b*) Lemma body with *tufts, or rows of tufts* of hairs, and smooth between the tufts, OR tufts of hairs *reduced or absent* 179

173. (*a*) Lemma body *longer* than lateral lobes which may be broad, acute or blunt, *not* or minutely awned; plants 10-40 cm high; panicle short (1.5-4 cm long and 1.5-2.5 cm wide) 174
(*b*) Lemma body *shorter* than or *equal* to lateral lobes 175

174. (*a*) Glumes broad; lemma broad; palea broadest above mid-point (2.3 mm wide) and narrowing below; inflorescence almost egg-shaped .... *Danthonia carphoides*
(*b*) Glumes and lemma narrower (3 mm wide); palea broadest towards middle (1-1.5 mm) *not* above the middle .... *Danthonia carphoides* var. *angustior*

175. (*a*) Lemma-back with scattered hairs *more than 1 mm long* grading into a *band of longer hairs* (4-5 mm long) above; panicle 8-15 cm long; anthers yellow .... *Danthonia procera*
(*b*) As for (*a*) but panicle 3-3.5 cm long; glumes *very dark maroon* .... undescribed *Danthonia* sp.
(*c*) Lemma-back with uniform scattered hairs *0.5 mm long* or less and much shorter than those in upper row 176

176. (*a*) Lateral lobes extended into *2 thin bristles* 4-6 mm long; hairs on lemma sparsely scattered or in 2 distinct rows .... *Danthonia setacea*
(*b*) Lateral lobes *shortly awned* (bristles 4 mm or less) or *awnless* 177

177. (*a*) Upper row of hairs *extending beyond awnless* or minutely awned lateral lobes; culms about 3-noded; leaves not flexuous 178
(*b*) Upper row of hairs *falling short of* lateral lobe bristles by 2-4 mm; culms 5-many noded; leaves long (up to 35 cm) and threadlike *Danthonia longifolia*

178. (*a*) Sheaths *almost or completely hairless*; ligule hairs short (0.5 mm); blades rolling and firm .... *Danthonia semiannularis*
(*b*) Sheaths *markedly hairy* (hairs about 3 mm long) with a long tuft of hairs at each side of ligule; blades soft and flat near ligule end *Danthonia semiannularis* var. *gracillis*

179. (*a*) Hair tufts *absent* or only partially developed with only dorsal or marginal tufts present, and *not in a complete row* across back of lemma 180
(*b*) Hair tufts in a *complete row* across back of lemma just below sinus 185

180. (*a*) Lemma body *shorter* than lateral lobes including long or short awns 181
(*b*) Lemma body *longer* than or almost as short as lateral lobes including bristles if present 184

181. (*a*) *Lateral hair tufts only* present; leaves bristly, hairless and smooth; small alpine perennial with panicle 2.5-8 cm long, and 5-6 flowered spikelets .... *Danthonia nudiflora*

(*b*) *Lower hair tuft present* with or without upper hair tufts; leaves not rigid, often hairy 182

182. (*a*) Central awn extending about 5 mm beyond lemma lobe bristles; *panicle 4-5 cm long,* contracted, upright and compact .... *Danthonia pilosa*

(*b*) *Panicle 5-15 cm* long slender, *not compact* 183

183. (*a*) Panicle *erect,* florets *exceeding* glumes; spikelets 7-10 flowered, ligule a ring of very short hairs (0.25 mm) .... *Danthonia racemosa*

(*b*) Panicle *drooping;* florets *included within glumes*; spikelets 4-6 flowered; ligule usually a minute jagged rim, sometimes a row of very short hairs .... *Danthonia penicillata*

184. (*a*) Panicle *3-6 cm* long; leaves soft and fine; complete lemma 4.5-7 mm long; spikelets *often reflexed* at flowering, lowland species .... *Danthonia dimidiata*

(*b*) Panicle *2-3 cm* long; leaves needle-like; complete lemma 3-4 mm long; small alpine perennial with usually 4-flowered spikelets *Danthonia nivicola*

185. (*a*) Lemma with *a second row of hair tufts* just above callus 186

(*b*) Lemma *without* a second row of hair tufts although marginal hair tufts may be present; inflorescence with a few spikelets (about 6) *Danthonia laevis*

186. (*a*) Lemma body *1.25-3 mm* long 187

(*b*) Lemma body *3 mm or more* long 189

187. (*a*) Lateral lobes plus bristles *less than 6 mm* long 188

(*b*) Lateral lobes plus bristles *6-10 mm* long .... *Danthonia setacea*

188. (*a*) Lemma body *2.5-3 mm* long; lemma lobes 2-4 mm long; twisted column of awn longer than or about equal to lemma lobes (+ short bristle), *lowland* species with 4-20 spikelets per panicle, and 4-6 florets per spikelet .... *Danthonia dimidiata*

(*b*) Lemma body *less than 2.5 mm* long; lemma lobes 1-2 mm long, without bristles or mucronate; *sub-alpine plant* with very small panicles with 4-6 spikelets and 3-5 florets per spikelet .... *Danthonia pauciflora*

189. (*a*) Bristles about 2 mm long (rarely up to 4 mm), *much shorter* than rest of lateral lobes 190

(*b*) Bristles *4 mm long* or more, *equal in length* to rest of lateral lobe 191

190. (*a*) Lemma body *about 3.5 mm long*; palea extending *just above* sinus base; anthers *dark orange-yellow*; plants 30-90 cm high .... *Danthonia purpurascens*

(*b*) Lemma body *4-5 mm* long; palea 7-8 mm long, extending *well beyond* sinus base; anthers *yellow*; plants 70-120 cm high .... *Danthonia procera*

191. (*a*) Palea *4.5-5 mm* long with a *long drawn out, narrow,* bifid, membranous tip much exeeding sinus base; panicle branches smooth, minutely rough or minutely hairy .... *Danthonia caespitosa*

(*b*) Palea *broadly egg-shaped* with minutely bifid apex only *shortly extending beyond base of sinus*; panicle branches downy or silky hairy .... *Danthonia eriantha*

192. (*a*) Glumes *almost equal,* the upper less than 6 mm long; spikelets 4-7 flowered 193

(*b*) Glumes very *unequal,* the upper 6-8 mm long; spikelets 2-4 flowered, lemma ending in *2 long (2-3 mm) and 2 short bristle-teeth* .... *Amphibromus archeri*

193. (*a*) Lemma ending in *4 equal teeth*; panicle narrow and dense; awn reddish-brown arising from *upper 1/3 of lemma* .... *Amphibromus recurvatus*

(*b*) Lemma *irregularly toothed*; panicle *very loose*; awn pale-brown arising from *just above the middle* of lemma .... *Amphibromus neesii*

A KEY TO 70 GRASSES FOUND IN TASMANIA USING VEGETATIVE CHARACTERS

1. (*a*) Ligule present (may be very small) 2
   (*b*) Ligule absent .... *Echinochloa crus-galli* var. *frumentacea* Japanese millet

2. (*a*) Blade very hard, bristle-like with a very sharp tip (pungent pointed); littoral species (growing on the beach) 3
   (*b*) Blade not as above 4

3. (*a*) Auricles present .... *Festuca littoralis* Coast fescue
   (*b*) Auricles absent .... *Stipa teretifolia* Coast speargrass

4. (*a*) Leaf bud *folded* V or ⍜ in cross section 5
   (*b*) Leaf bud *rolled* ⍥ in cross section 31

5. (*a*) Auricles present 6
   (*b*) Auricles absent 8

6. (*a*) Blade wide (2 mm wide and more), lower surface glossy 7

(*b*) Blade narrow (1 mm wide or less), lower surface dull with minute forward pointing teeth or barbs, *very rough* when rubbed from tip backwards	*Nassella trichotoma*	Serrated tussock	
7. (*a*) Sheaths usually split right down, with overlapping margins; perennial; ligule usually 1 mm or less (up to 2 mm)	*Lolium perenne*	Perennial ryegrass	
(*b*) Young sheaths not split right down (oldest may be); self-regenerating annual; ligule 2 mm long or more	*Lolium rigidum*	Wimmera ryegrass	
8. (*a*) No hairs present in position of auricles			9
(*b*) Hairs present in position of auricles			23
9. (*a*) Ligule a membrane			10
(*b*) Ligule a fringe of hairs	*Pennisetum clandestinum*	Kikuku grass	
10. (*a*) Ligule very small (0.5 mm-1.5mm)			11
(*b*) Ligule prominent (2 mm-8 mm)			17
11. (*a*) Leaf sheath split right down			12
(*b*) Leaf sheath not split to base			15
12. (*a*) Blades rough if lightly rubbed			13
(*b*) Blades not rough to touch			14
13. (*a*) Sheaths hairless; blades involute, shiny, 1-3 feet long	*Poa poiformis*	Blue Tussock grass	
(*b*) Sheaths hairless, blades ± flat, dull, about 6 inches long	*Dichelachne crinita*	Long hair plume grass	
(*c*) Sheaths hairy, blades involute, finely hairy	*Stipa pubescens*	Tall speargrass	
14. (*a*) Rhizomes present	*Poa pratensis*	Kentucky blue grass	
(*b*) Rhizomes absent; yellow colour at base of lowest living sheaths	*Cynosurus cristatus*	Crested dog's tail	
15. (*a*) Blades 1 mm wide or less, bristle-like; plants without rhizomes			16
(*b*) Blades >2 mm wide with hooded (boat-shaped) tip, plants with rhizomes	*Poa pratensis*	Kentucky blue grass	
16. (*a*) Blades and sheaths with many fine short hairs	*Poa australis*	Tussock grass	
(*b*) Blades and sheaths quite hairless	*Festuca rubra* Sub. sp. *commutata*	Chewing's fescue	
17. (*a*) Leaf sides parallel with boat-shaped tip			18
(*b*) Leaf sides taper to tip			21
18. (*a*) Rhizomes present	*Glyceria maxima*	Water meadow grass	
(*b*) Rhizomes absent			19
19. (*a*) Red colour present on sheaths especially lower ones	*Glyceria australis*	Australian sweet-grass	
(*b*) Sheaths green			20
20. (*a*) Plant with stolons; sheaths with prominent cross veins	*Glyceria declinata*	Glaucous Sweet-grass	
(*b*) Plant without stolons; no cross veining on sheaths	*Poa annua*	Annual poa	
21. (*a*) A densely tufted fleshy perennial with very broad (2-12 mm) strongly folded and keeled blades and sheaths; lower leaf sheaths sometimes hairy (coarsely); ligules up to 12 mm long	*Dactylis glomerata*	Cocksfoot	
(*b*) Annual with leaf blades not wider than 3 mm			22
22. (*a*) Leaf blades up to 3 mm wide, open	*Dichelachne crinita*	Longhair plume grass	
(*b*) Leaf blades about 0.3 mm wide, inrolled	*Aira caryophyllea*	Silvery hair grass	
23. (*a*) Leaf blades broad (when flattened if rolled) (>2 mm wide)			24
(*b*) Leaf blades narrow (<2 mm wide)			27
24. (*a*) Plant without stolons, ligule membranous			25
(*b*) Plant with stolons, ligule a fringe of hairs			26
25. (*a*) Sheath margins fringed with distant hairs	*Stipa variabilis*	Spear grass	
(*b*) Sheath margins not fringed	*Stipa nervosa*	Spear grass	
26. (*a*) Leaves with few long hairs, blade T.S. V-shaped, under surface fairly dull, upper surface rough when rubbed downwards	*Stenotaphrum secundatum*	Buffalo grass	

	(*b*) Leaves without hairs, under surface glossy, leaf smooth	*Hemarthria uncinata*	Mat grass
27.	(*a*) Plant with rhizomes and/or stolons, leaves distichous		28
	(*b*) Plant without rhizomes or stolons, leaves not distichous		29
28.	(*a*) Leaf blades stiff with inrolled margins and shining under-surface	*Distichlis distichophylla*	Australian Salt grass
	(*b*) Leaf blades not stiff, open and flat, with dull under-surface	*Cynodon dactylon*	Couch
29.	(*a*) Leaves rough if lightly rubbed; ligule fringed with hairs	*Stipa mollis*	Speargrass
	(*b*) Leaves not rough		30
30.	(*a*) Leaf blades open and flat, older leaves and culms with deep maroon colouring; margins of young blades and lowest leaf sheaths with scattered long white hairs, older leaves hairless	*Themeda australis*	Kangaroo grass
	(*b*) Leaf blades very narrow, usually inrolled and folded, grey-green colour, hairy, sometimes with maroon colouring	*Danthonia* spp.	Wallaby grasses
31.	(*a*) Ligule a prominent membrane (2 mm+)		32
	(*b*) Ligule minute (membrane <1 mm) or absent or replaced by a fringe of hairs		54
32.	(*a*) Blades and sheaths hairless		33
	(*b*) Blades and/or sheaths with hairs		46
33.	(*a*) Leaf margins serrate (use lens)		36
	(*b*) Leaf margins smooth, not serrate		34
34.	(*a*) Annual, culms slender, up to 2 feet high	*Briza* spp.	Quaking grass
	(*b*) Perennial		35
35.	(*a*) Leaf stiff, upper surface white and deeply ridged, usually rolled, at least above; rhizomatous plant growing in sand dunes	*Ammophila arenaria*	Marram grass
	(*b*) Leaf not stiff, plant not or only very shortly rhizomatous, stem bases swollen; forage grass	*Phalaris tuberosa*	Toowoomba Canary grass
36.	(*a*) Surface(s) of blade apart from margin smooth to the touch		37
	(*b*) Surface(s) of blade rough		40
37.	(*a*) Plant with stolons only (not rhizomes)	*Agrostis stolonifera*	Creeping bent.
	(*b*) Plant without stolons, tufted or with very short rhizomes		38
38.	(*a*) Upper surface of leaf fairly smooth, culms stout, basal 1-3 internodes very short, usually swollen or bulbous	*Phleum pratense*	Timothy grass
	(*b*) Upper leaf surface deeply ridged, stem bases not swollen		39
39.	(*a*) Tufted annual usually growing in sand near the sea, basal leaves light brown	*Agrostis billardieri*	Coastal blown grass
	(*b*) Tufted perennial associated with pastures, basal leaves turning dark brown	*Alopecurus pratensis*	Meadow foxtail
40.	(*a*) Auricles present		41
	(*b*) Auricles absent		42
41.	(*a*) Blade flat, shining beneath and curving gently	*Festuca arundinacea*	Tall fescue
	(*b*) Blade often inrolled, stiff and straight, not shining	*Deyeuxia quadriseta*	Reed Bent grass
42.	(*a*) Annual species		43
	(*b*) Perennial species		45
43.	(*a*) Blade deeply ridged on upper side, culms slender usually <2 feet high		44
	(*b*) Blade fairly smooth on upper side, culms stout, up to 5 feet high	*Avena fatua*	Wild oats
44.	(*a*) Leaf blade narrow (1-2 (3) mm wide) often rolled along its length	*Agrostis aemula*	Blown grass
	(*b*) Leaf blade (at least middle ones) wide (4-6 mm wide) flat	*Phalaris minor*	Lesser Canary grass

45. (*a*)	Robust plant spreading extensively by creeping rhizomes; often with prominent cross-veins on blades and sheaths; growing in damp situations	*Phalaris arundinacea*	Reed Canary grass
(*b*)	Plant tufted, without rhizomes, culms stiff and reed-like; under-surface of blade glossy, top surface rough, blades becoming harsh and often maroon coloured from the tip down	*Oryzopsis miliacea*	Rice millet
46. (*a*)	Annual species		47
(*b*)	Perennial with tufted habit, or rhizomes or stolons		48
47. (*a*)	Sheath not split to base; ligule 3-6 mm long, jagged	*Bromus diandrus*	Great brome
(*b*)	Sheath split right down to base, upper sheaths somewhat inflated; ligule up to 3 mm long, hairy	*Lagurus ovatus*	Hairstail grass
48. (*a*)	Plant tufted without stolons, rhizomes or bulbils		52
(*b*)	Plant with stolons, rhizomes or bulbils		49
49. (*a*)	Plant forming dense thick growth with strings of bulbils at bases of culms	*Arrenatherum elatius* var. *bulbosum*	Bulbous oat grass
(*b*)	Plant spreading by means of rhizomes or stolons; without bulbils		50
50. (*a*)	Plant with rhizomes and long stolons forming a dense low mat, blades hairless, sheaths with hairs	*Paspalum distichum*	Water couch
(*b*)	Plant with rhizomes only, tall robust grass, blades and sheaths with hairs		51
51. (*a*)	Under-surface of leaf blades highly glossy	*Hierochloë redolens*	Sweet holy grass
(*b*)	Under-surface of leaf blades dull	*Paspalum dilatatum*	Paspalum
52. (*a*)	Sheath not split right down to base, leaves rough if lightly rubbed	*Bromus unioloides*	Prairie grass
(*b*)	Sheath split right down		53
53. (*a*)	Sheaths and blades densely hairy (pubescent) soft and downy to touch, lower sheaths with pink veins on white background, innermost leaf-sheath *pubescent to base*	*Holcus lanatus*	Yorkshire fog
(*b*)	Sheaths loosely to densely bearded at the top, otherwise smooth or loosely hairy; veins green; blades loosely hairy or hairless, rough or smooth	*Anthoxanthum odoratum*	Sweet vernal
54. (*a*)	Ligule a fringe of hairs (v. short membrane (<0.1 mm) in addition may be present in *Sporobolus*)		55
(*b*)	Ligule a minute membrane (0.5 mm-1 mm, may or may not be fringed with hairs); or absent		60
55. (*a*)	Plant with rhizomes		58
(*b*)	Plant without rhizomes (stolons present or habit tufted)		56
56. (*a*)	Plant very hairy and silvery in appearance with very long sprawling stolons, growing on sand dunes	*Spinifex hirsutus*	Hairy Spinifex
(*b*)	Plant not so		57
57. (*a*)	Leaves stiff and sharply pointed, harsh, often inrolled in dry conditions, with little tuft of white hairs in position of auricles, perennial	*Sporobolus capensis*	Paramatta grass
(*b*)	Leaf blades broad (4-10 mm wide) finely pointed, hairless, sheaths hairy on margins; annual sp.	*Setaria* spp. (*S. viridis* and *S. verticillata*)	Pigeon grass

58. (*a*)	Robust deep-rooting perennial with soft fleshy rhizomes forming dense patches growing in muddy tidal saltmarshes and mudflats, e.g., Tamar River; sheaths have cross veins	*Spartina townsendii*	Townsend's Cord grass
(*b*)	Plant not so		59
59. (*a*)	Blades and sheaths without hairs except for tuft of silky hairs in position of auricles and at nodes; blades broad (4-6 mm) and very stiff, narrowing to fine point; rhizomes fairly stout	*Imperata cylindrica*	Blady grass
(*b*)	Blades and usually sheaths hairy; blades soft, open and flat, narrow, rather short (1-3 inches), often curving out from more or less wiry stems; rhizomes very thin and wiry	*Microlaena stipoides*	Weeping grass
60. (*a*)	Auricles present (obvious claw-like outgrowths at blade-sheath junction)		61
(*b*)	Auricles absent		65
61. (*a*)	Under-surface of blade with high gloss, upper-surface much ridged		62
(*b*)	Under-surface of blade dull, not shining		63
62. (*a*)	Leaves very stiff and harsh, unless young, with rough cutting edges; coarse tufted perennial forming tussocks especially on wet ground	*Festuca arundinacea*	Tall fescue
(*b*)	Leaves not stiff and harsh, blades smooth to the touch	*Lolium multiflorum*	Italian ryegrass and Short rotation rye grass
63. (*a*)	Plant spreading by means of rhizomes; blades rough when lightly rubbed downwards	*Agropyron repens*	English Couch
(*b*)	Plant without rhizomes		64
64. (*a*)	Blades narrow (about 2 mm wide) rough, deeply ridged on upper-surface, and stiff	*Agropyron scabrum*	Common wheat grass
(*b*)	Blades wide (about 5 mm wide), fairly smooth on upper-surface, soft to touch, not stiff	*Hordeum leporinum*	Barley grass
65. (*a*)	Sheath split right down to base		66
(*b*)	Sheath split only part way down to base, blades and sheaths softly hairy, small annual or biennial species with loosely tufted or solitary culms, innermost leaf-sheath pubescent to about *halfway to base*	*Bromus mollis*	Soft brome
66. (*a*)	Perennial with broad leaves, blades about 9 inches long, often rolling		71
(*b*)	Leaf blades much shorter		67
67. (*a*)	Perennial spreading by rhizomes, stolons may be present	*Agrostis tenuis*	Brown top bent.
(*b*)	Annual species without rhizomes or stolons		68
68. (*a*)	Mature plant mostly purple-coloured, blades and sheaths very hairy	*Digitaria sanguinalis*	Summer grass
(*b*)	Plant not mostly purple		69
69. (*a*)	Blades rough, hairless; sheaths with or without hairs	*Dichelachne sciurea*	Short hair plume
(*b*)	Blades very narrow and bristle-like, not rough, with short hairs, sheaths hairless	*Vulpia* spp.	Squirrel tail fescue, etc.
70. (*a*)	Blades and sheaths hairless except for tuft of silky hairs in position of auricles and at nodes; plant with fairly stout rhizomes	*Imperata cylindrica*	Blady grass
(*b*)	Sheaths hairy		71
71. (*a*)	Blades hairless, undersides glossy		72
(*b*)	Blades densely hairy; appearing silvery	*Stipa stuposa*	Spear grass
72. (*a*)	Blades smooth on upper surface, often red colour on plant near ground level	*Stipa compacta*	Spear grass
(*b*)	Blades rough on upper surface, sheaths silvery pubescent	*Stipa semibarbata*	Spear grass

GLOSSARY

abaxial: side away from axis
acuminate: tapering to a point in hollow curves
acute: tapering to a sharp point in straight lines
adaxial: side towards the axis
aristate: awned
ascending: sloping upwards; applied to stems which curve from the base upwards
auricles: small claw- or ear-like outgrowths at junction of blade and sheath of some grasses
auriculate: having auricles
barbed: bearing backward pointing teeth
bidentate: with two points or teeth at tip
bulbil: a little bulb; swollen base of the stem
callus: hardened basal projection at the base of the floret or spikelet usually incorporating the scar of attachment
capitate: head-like
capillary: hair-like
chartaceous: of papery texture
coriaceous: of leathery texture
culm: jointed stem of grasses
denticulate: with very small teeth pointing outwards
digitate: several members borne at top of support, e.g., racemes at top of peduncle or flowering stalk as in *Cynodon dactylon*
sub-digitate: one or two of members borne slightly lower down penduncle
dioecious: male flower on one plant, female flower on another
distant: separate from each other
distichous: conspicuously 2-ranked
dorsal compression: (of spikelet or floret) flattened from back to front, i.e., middle of lemma brought close to its margins so that two keels are formed
exserted: projecting beyond enclosing structure
filiform: thread-like
flexuous: wavy
floret: lemma and palea with the enclosed flower; florets may be bisexual and perfect, or unisexual and male or female, or reduced to the lemma
glabrous: without hairs
glaucous: bluish-green, often because of a covering of wax or thick white skin; covered with a bloom like a plum
glume: two (usually) empty bracts at the base of the spikelet, called the lower and upper glumes
grain: caryopsis or naked seed of grasses
hilum: scar of attachment of ovule to ovary wall (in grasses)
hoary: grey with a covering of fine soft hairs (pubescence)
hyaline: transparent
indurated: hard
inflorescence: flowering head
involucre: a whorl of bracts
involute: with the margins rolled inwards
keel: sharp fold or ridge at the back of a compressed sheath, blade, glume, lemma or palea
lanceolate: lance-shaped; widest in the lowest-third and gradually narrowed upwards, 3 times as broad as long; if longer or wider would be described as narrowly or broadly lanceolate
lateral compression: (of spikelet or floret) flattened from side to side so that structure has one keel down the middle
lemma: lower of two bracts enclosing the flower (lodicules, stamens, ovary), = flowering glume or valve
linear: long and narrow, with parallel sides, ratio of length to breadth = 12 or more to 1
littoral: growing on the beach; *sublittoral* growing near the beach, e.g., on dune slacks
mucro: a sharp terminal point, a minute awn, *mucronate*—having a mucro
nerve: vein: slender rib marking position of strengthening tissue in leaves, glumes, lemmas and paleas
oblong: with parallel sides, longer than wide in the ratio of about 2 to 1; if longer or wider is described as narrowly or broadly oblong
obovate: ovate outline inverted
obtuse: blunt; applied to the tip of a leaf or bract
ovate: egg-shaped in outline, about twice as long as broad, tapering to the tip; also, narrowly and broadly ovate when longer or wider
ovoid: egg-shaped solid
palea: upper of two bracts enclosing the lodicules stamens and ovary = valvule or upper palea
pallid: pale, light coloured
panicle: a compound raceme with spikelets on branches (stalk or pedicel) of branches of the inflorescence
papillose: covered in papillae or little bumps
pectinate: comb-like
pedicel: the spikelet-stalk
pubescent: downy, covered with fine soft hairs
pungent-pointed: with very sharp hard point
raceme: inflorescence with spikelets on stalks on the unbranched main axis
rachilla (or *rhachilla*): main axis of spikelet
rachis (or *rhachis*): main axis of inflorescence
recessed: sitting in a hollow
reflexed: bent or turned backwards or downwards
retrorse: directed backwards or downwards
rhizome: underground stem, bearing scale-like leaves
scabrous: rough to the touch
scabrid and *scaberulous*: minutely scabrous
secund: all directed to one side
serrate: saw-toothed
serrulate: minutely serrate
seta: bristle
setaceous: bristle-like
sinus: gap between two apical lobes
spike: unbranched inflorescence with sessile spikelets
spikelet: unit of the grass inflorescence, usually composed of two glumes and one or more flowers each borne between a lemma and a palea
spike-like: resembling a spike, as in very dense racemes and panicles with very short lateral branches
stolon: a runner or creeping stem (above ground) rooting at the nodes and giving rise to vegetative shoots and culms
subterminal: just below the tip
subulate: awl-shaped, cylindrical in section and ending in a point
terete: circular in cross-section

terminal: at the tip
truncate: ending abruptly as if cut off
tuberculate: with knobby projections
vein: see nerve
whorl: several at a node

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REFERENCES

BLACK, J. M., 1960—*Flora of South Australia. Part* 1, 2nd Ed. Govt Printer, Adelaide.

GARDNER, C. A., 1952—*Flora of Western Australia. Vol.* 1, *Part* 1. *Gramineae.* Govt Printer, Perth.

HITCHCOCK, A. S., 1950—*Manual of the Grasses of the United States* 2nd Ed. Revised AGNES CHASE. U.S.D.A. Miss. Publ. 200.

HUBBARD, C. E., 1954—*Grasses. A Guide to their Structure, Identification, Uses, and Distribution in the British Isles* Pelican Books, A295.

HUGHES, D. K., 1921—A Revision of the Australian Species of *Stipa. Kew Bull.* 1921.

RODWAY, L., 1903—*The Tasmanian Flora* Govt Printer, Hobart.

VICKERY, J. W., 1939—Revision of the Indigenous Species of *Festuca* Linn. in Australia. *Contrib. N.S.W. Nat. Herb.* (1939) 1: 5-15.

———, 1940—A Revision of the Australian Species of *Deyeuxia* Clar. ex Beauv., with Notes on the Status of the Genera *Calamagrostis* and *Deyeuxia. Contrib. N.S.W. Nat. Herb.* (1940) 1: 43-82.

———, 1941—A Revision of the Australian Species of *Agrostis* Linn. *Contrib. N.S.W. Nat. Herb.* (1941) 1: 101-120.

———, 1956—A Revision of the Australian Species of *Danthonia* DC. *Contrib. N.S.W. Nat. Herb.* (1956) 2: 249-325.

———, 1963—*Dryopoa*, a New Grass Genus Allied to *Poa. Contrib. N.S.W. Nat. Herb.* (1963) 3: 195-197.

WILLIS, J. H., 1962—*A Handbook to Plants in Victoria. Vol.* 1. *Ferns, Conifers and Monocotyledons.* U.P. Melbourne.

ON TWO RECORDED SPECIES OF TERTIARY FORAMINIFERA FROM FOSSIL BLUFF, WYNYARD

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(With one plate)

ABSTRACT

Reophax lodderae and *Nodosaria roemeri* Neugeboren var. *semicostata* were described by Goddard and Jensen from Fossil Bluff in 1907. *Reophax lodderae* probably is not a foraminifer but a broken echinoid spine. *Nodosaria roemeri* var. *semicostata* is renamed *Dentalina godjeni*, as *semicostata* and *costata* are preoccupied.

INTRODUCTION

Goddard and Jensen (1907) recorded foraminifera from Fossil Bluff (now regarded as Lower Miocene). The ' material was obtained from the debris of fossil mollusca collected at Table Cape ', probably from the lower part of the section, as this is the only part of the section from which I can find the species remarked upon here.

In their paper, they described three new species. These were *Frondicularia trimorpha, Reophax lodderae* and *Nodosaria roemeri* var. *semicostata* (*N. costata* in plate explanation).

During a recent study on Tasmanian Tertiary foraminifera, I encountered two of the species they described, namely *Reophax lodderae* and *Nodosaria roemeri* var. *semicostata*. Both of these species deserve comment.

Goddard and Jensen did not list a repository for their type specimens. Dr A. Ritchie, Australian Museum and Dr P. Stanbury, Macleay Museum, have helped in the fruitless search for the specimens. Hence I must rely on Goddard and Jensen's figures and brief descriptions.

The newly separated specimens described are housed in the collections of the University of Tasmania, Geology Dept, and the number after the symbol U.T.G.D. represents the specimen number in that collection.

I am indebted to Mr M. R. Banks, University of Tasmania for criticising the manuscript.

1. *Reophax lodderae* Goddard and Jensen, 1907

(Figure 1)

Reophax lodderae probably is not a foraminifer. It is a small hollow echinoid spine. The specimen figured by Goddard and Jensen shows three ' chambers ', the boundaries of which are delineated by the ends of several ' spicules '. I have recovered from the Freestone Cove Sandstone a single specimen of an echinoid spine which has the characters they describe. The specimen is 1.5 mm long (twice the length of the specimen Goddard and Jensen described) and has the appearance of having five chambers, almost twice as many as their specimen. It also has a hollow core. In the new specimen, the ' spicules ' do not terminate quite as regularly as Goddard and Jensen suggest, although the terminations are not random. The ' chamber ' size, width of the specimen, characters of the ' spicules ' and all other characters suggest that the two specimens belong to the same species.

Maximum diameter of figured specimen 1.52 mm.

Repository: U.T.G.D. 84552.

2. *Nodosaria roemeri* var. *semicostata* Goddard and Jensen, 1907

(Figure 2)

The species described by Goddard and Jensen as *Nodosaria* has a curved growth axis and thus belongs not to *Nodosaria* Lamarck but *Dentalina* Risso. The names *costata* and *semicostata* are both preoccupied several times, the former by *D. costata* de Pourtales, 1850 (*?nomen nudem*), by *D. costata* Eichwald 1853 (questionably a *Nodosaria*) and perhaps by *Nautilus* (*Orthoceras*) *costatus* Batsch, 1791 [*Marginulina costata* (Batsch)]. *D. semicostata* is preoccupied by *D. semicostata* d'Orbigny, 1846 and *N.* (*Dentalina*) *pungens* var. *semicostata* (Reuss).

As both names proposed by Goddard and Jensen (1907) are preoccupied, the species is herein renamed *Dentalina godjeni* n. name, in honour of the original authors. The name is made up of *God*dard and *Jen*sen.

Description

Test free, uniserial, arcuate, circular in section, of about 10 chambers, forming a test on the average 4-5 mm long. All chambers but the last one or two bear about eight to ten longitudinal costae which become fainter on the later chambers. These costae are arranged slightly spirally, twisting through about 90° during the development of eight chambers. The later chambers are smooth. Aperture terminal, radiate, on the concave side of the test. Sutures moderately depressed in the last one or two chambers, almost flush in earlier chambers. Sutures initially perpendicular to the test axis, later often becoming slightly oblique, directed slightly basally on the concave side.

Chambers increase uniformly slowly in size except for the ultimate chamber which may be smaller than several preceding chambers.

The species is distinct from most initially costate forms in not having an initial spine at its basal end.

Occurrence and Age

Specimens of *D. godjeni* were recovered from Mussel Roe Bay (offshore specimens) in rocks which may be Upper Oligocene (U.T.G.D. 84483). The species is an obvious one in samples from the lower part of the Fossil Bluff section in rocks which are Lower Miocene (U.T.G.D. 84010 a and b).

Figured specimen from Fossil Bluff (84010a).

Maximum diameter of figured specimen 4.4 mm (lectotype).

Repository: U.T.G.D.84293.

Reference

Goddard, E. J. and Jensen, H. I., 1907—Contributions to a knowledge of Australian foraminifera—Part II. *Proc. Linn. Soc. N.S.W.* Vol. 32, Pt. 2, pp. 291-318, pl. 6.

Fig. 1.—'*Reophax lodderae* Goddard and Jensen'. U.T.G.D. 84552. Lateral view, ×38.

Fig. 2.—*Dentalina godjeni* n. name; lectotype, U.T.G.D. 84293, ×14.

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